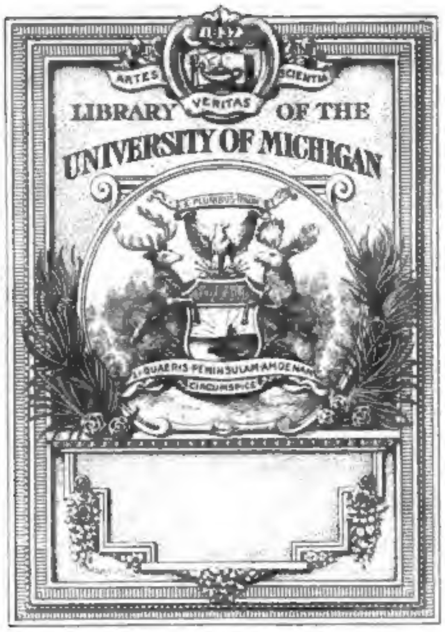
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IOWA

GEOLOGICAL SURVEY

VOLUME XV.

ANNUAL REPORT, 1904,

WITH

ACCOMPANYING PAPERS.

FRANK A. WILDER, PH. D., STATE GEOLOGIST.
T. E. SAVAGE, ASSISTANT STATE GEOLOGIST.

DES MOINES
PUBLISHED FOR IOWA GEOLOGICAL SURVEY
1905.

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BERNARD MURPHY, STATE PRINTER
1905.

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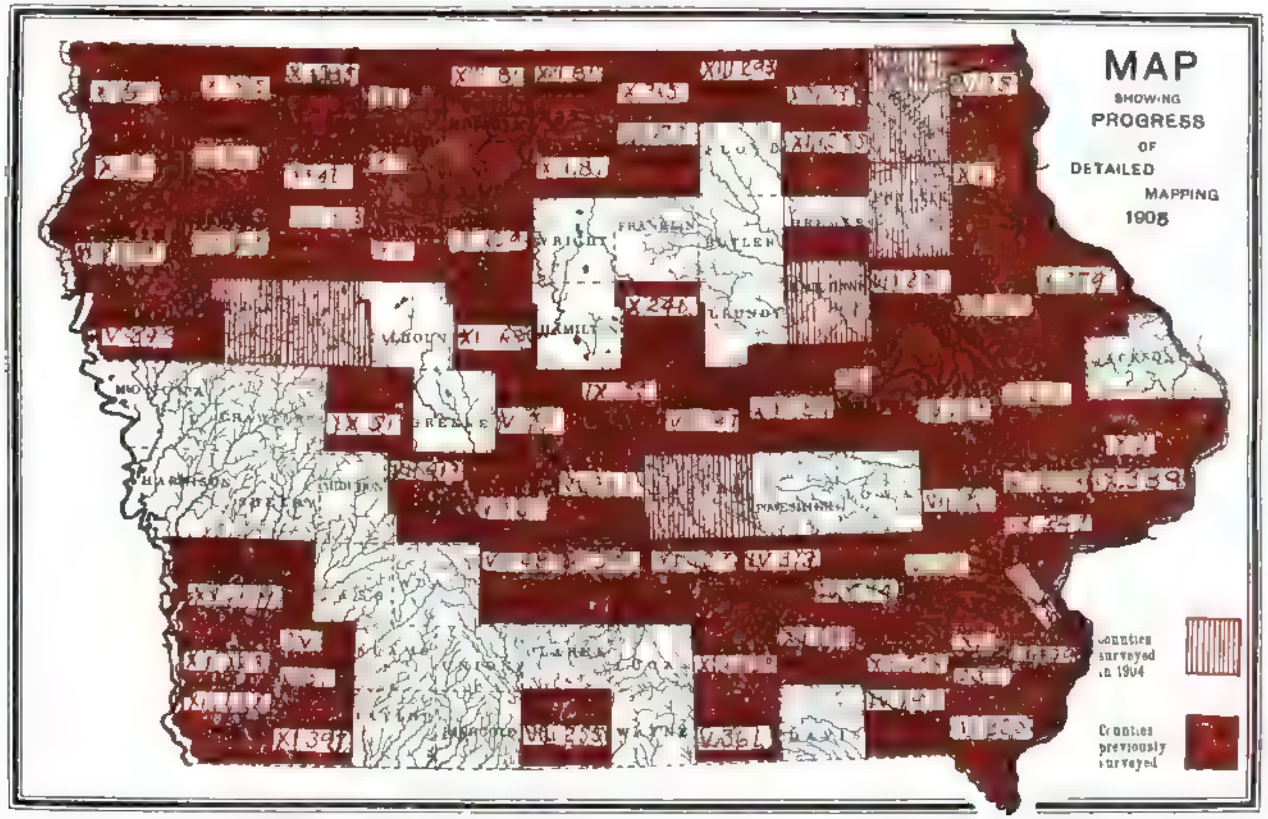
CONTENTS.

LIST OF ILLUSTRATIONS.

FIGURES.

ADMINISTRATIVE REPORTS.


MAP
SHOWING
PROGRESS
OF
DETAILED
MAPPING
1905
Counties
surveyed
in 1904
Counties
previously
surveyed

THIRTEENTH ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,

DES MOINES, DECEMBER 31, 1904.

To Governor Albert B. Cummins and Members of the Geological Board:

GENTLEMEN:—It is my privilege to report the progress that has been made during the past year in carrying out the plans for work that were approved by you a year ago. The resignation of Professor Calvin, who submitted these plans to you and who has guided the investigations of the Survey from its beginning, was a matter of keen regret to all those who are interested in the work of the Survey throughout the state and the country at large. It is fitting at this time to call attention to the high plane to which the Survey has been raised during his administration. I can not do so more appropriately than by quoting a reliable writer for the Mining Reporter of Denver for February 23, 1903. "For types of successful University Surveys it is only necessary to refer to the magnificent history of the Wisconsin Survey, whose publications have come to be regarded as classics in Geological literature; the Iowa Survey under the charge of Professor Calvin, of the State University, whose work has been so favorably commented on by the Geological and Engineering Journals; the Maryland Survey, in charge of the department of Geology in Johns Hopkins University, has been a model of economy and economic efficiency as well as scientific excel-

lence. Among the many others may be specifically mentioned the present New York Survey, and the Texas Survey established within the past few years at the State University, and already recognized as an important factor in the recent development of the state."

It gives me great pleasure to report that Professor Calvin will retain an active interest in the work of the Survey, and the relief afforded him from routine and executive duties will enable him to push forward the important monographs that he has undertaken on the stratigraphy and paleontology of the state.

On account of the removal of Prof. J. B. Weems from the state, Prof. Louis G. Michael of the Iowa State College, at Ames, was appointed Survey Chemist by you and is serving in that capacity.

In addition to the preparation of a number of county reports during the past year, more time than heretofore has been devoted to some of the larger economic problems with the purpose of publishing results in a convenient form to meet a real and growing demand for information in regard to the quarry and cement materials; the coal; and the gypsum of the state. A preliminary report on the Portland cement industry and Iowa's natural resources with reference to Portland cement, prepared by Edwin C. Eckel and H. F. Bain of the United States Geological Survey, is published this year. This report is a product of the helpful co-operation of the State and National Geological Surveys, a co-operation which has been efficient along a number of lines during the year. The report shows plainly that the limestones and clays of Iowa are a proper field for the careful study of the cement manufacturer, and it is believed that this preliminary report will attract the attention of capital seeking investment along this line. A number of urgent requests for this report, from responsible parties, are already on file. A more thorough study, looking to a complete report on Portland cement possibilities in Iowa, is now being undertaken by Dr. S. W. Beyer in connection with his investigation of quarries and quarry products within the state. The field work on these reports will require at least another summer.

The series of coal tests that have been undertaken by the Iowa Geological Survey, co-operating with the United States Survey, promises to bring out facts that will be of interest to every user of coal. The coal was in all cases donated by mine operators and in every instance but one carried without charge by the railroad companies. Five car loads of coal from as many important mines in Iowa have already been tested, and with the results obtained it will be possible to illustrate the nature and significance of the work. For the first time in the history of the country coal from practically all of the coal producing states has been brought to a single, well equipped plant, and has been tested under the same conditions and by the same men, whose position guarantees a fair and impartial statement of results.

A study of the figures which follow will lead to the conclusion that in general the coals imported into Iowa are selling at a price that is too high, when their efficiency is compared with the Iowa coals which are put on the home market at a price considerably below the imported commodity.

When burned under the boilers at the Saint Louis testing plant, the Iowa coals, on the average, yielded energy sufficient to maintain a horse-power for an hour for each 3.9 pounds of fuel burned. For six samples of Illinois coal, the average amount of coal burned per horse-power hour was 3.7; for one sample of Pennsylvania coal, 3.1; and for thirteen samples of West Virginia coal, 3 pounds per horse-power hour.

The conditions under which these tests were made represent fairly the conditions that prevail in the average power plant of moderate size. The Illinois coals, from the fields tested, which are extensively used in the eastern part of the state, and are often given a decided preference over Iowa coals, should sell at practically the same price as the average Iowa coal. A study of the chemical analyses of the coals from the two states, made in connection with these tests, indicates that for domestic purposes the same statement is true, for the content in sulphur and ash in the coals from the two states is about the same, and certainly the advantage is not with the Illinois coals in these particulars.

The laboratory tests as to the heating qualities of the coals tallies with the tests in the power plant. The Iowa coals gave

on the average 6,300 calories, and 11,000 British thermal units, and the same figures represent the value of the Illinois coals in these tests. The Pennsylvania coal tested gave results one-twelfth better, and twelve samples of West Virginia coal were one-sixth higher.

By washing the Iowa coal, as is done commonly in the east, at a cost of six cents a ton, the per cent of ash was reduced four per cent, and the amount of sulphur one per cent. Coking tests were made on four of the Iowa coals, in the ordinary beehive oven. On the average, 8,500 pounds of coal yielded 3,500 pounds of coke, of a rather inferior quality, and these tests were not encouraging.

In the briquetting tests, it was found advantageous to use eight per cent of tar as a binder, and it was satisfactorily shown that the fine coal waste of Iowa can be prepared and put upon the market as a satisfactory fuel by this process.

The important producer gas tests are yet to be made with the Iowa coals, and the probabilities are that they will be successful, though there will exist the necessity of washing the gas to remove the excess of sulphur. This process, however, is simple and inexpensive.

It is hoped that coal from a number of important localities may be tested at the Saint Louis plant during the coming summer.

During the past summer I was engaged in selecting and securing the donation of these car-load samples, and in negotiations which led to the granting, in most cases, of free transportation from the mine to the testing plant at Saint Louis. In addition, while in the coal fields engaged in this work, considerable new light was gained in regard to extensive coal beds particularly in Marion and Lucas counties.

Preliminary tests to determine the economic temperature for calcining gypsum, were carried on at the laboratories of the State University during the summer of 1904. The gypsum industry in Iowa has an annual output valued at more than $500,000, and the state should assist other producing states, notably Michigan and Kansas, by contributing her part to an important technical literature on this subject. It is believed

that the Iowa gypsum industry will admit of a considerable expansion, and that a knowledge of newer methods applicable to the making of hard wall plasters will result in profit not only to the gypsum industry but to the whole state.

Professor Calvin has been engaged throughout the year in work on stratigraphic problems, and in collecting and compiling data for a final report on the drift. He has identified fossils for a number of Survey assistants and has rendered them important aid in the field.

Desiring to aid the high schools of the state in their science work, and appreciating their need of illustrative material, the Survey early in the fall proposed to share with the schools some of the material that it has brought together. To determine the interest of the high schools in the movement, the following circular letter was addressed to the high school principals:

The Iowa Geological Survey, through its representatives in the field, is able to bring together at little expense, an excellent collection of the rocks, fossils and minerals of Iowa.

The Survey proposes to send a set of thirty labeled specimens to each high school in the state. A detailed account of the specimens intended to be helpful to teachers and pupils will accompany each set. The high school receiving the specimens will be asked to pay $1.00 for specimen trays and packing, and the express charges. The purpose of this nominal charge is primarily to insure the Survey of a reasonable interest in the material on the part of the recipients.

Before undertaking the work an expression of opinion from the high schools is desired. Will your school care to co-operate if the plan is carried out?

Very truly yours,
FRANK A. WILDER,
University of Iowa,
Iowa City, Iowa.

More than one hundred and twenty schools sent in requests for the collections, this number exceeding considerably the anticipated demand. One hundred sets, representing 4,000 specimens were sent out and were well received by the high school authorities. At a later date it will be possible to supply the remaining applicants and others who may apply.

The following specimens were included in each collection:

SAMPLE.

Sioux quartzite.
Maquoketa shale.
Shell limestone.
Carboniferous sandstone.
Carboniferous shale.
Striated glacial pebble.
Glacial granite.
Decayed granite.
Loess and loess kindchen.
Lead ore from Dubuque.
Waukon iron.
Quartz geode.
Calcite geode.
Rock gypsum.
Selenite.
Satin spar.
Iron pyrites.
Peat.

FOSSILS.

Pentamerus oblongus.
Favosites favosus.
Halysites catenulatus.
Orthoceras sociale.
Acervularia davidsoni
Orthis impressa.
Orthis iowensis.
Atrypa reticularis.
Spirifer pennatus.
Spirifer hungerfordi.
Spirifer mucronatus.
Athyris spiriferoides.
Ptyctodus calceolus (teeth).
Spirifer keokuk.
Athyris subtilita.
Inoceramus labiatus.

Pasteboard trays and carefully prepared labels were furnished with each specimen and each set was accompanied by a descriptive pamphlet of ten pages.

The following list includes the schools receiving the material:

Adel.
Akron.
Albia.
Alton.
Anamosa.
Bellevue.
Belmont.
Boone.
Brighton.
Brooklyn.

Burlington.
Boynton.
Cedar Rapids.
Charles City.
Centerville.
Coon Rapids.
Correctionville.
Corning.
Clinton.
Cincinnati.
Corydon.
Council Bluffs.
Davenport.
Decorah.
Des Moines, Capital Park School.
Des Moines, Oak Park School.
Des Moines, West High School.
Eagle Grove.
Eddyville.
Eldora.
Emmetsburg.
Exira.
Fairview.
Farmington.
Fonda.
Fort Dodge.
Garner.
Glenwood.
Grand River.
Grimes.
Grundy Center.
Guttenberg.
Hawarden.
Hedrick.
Hiteman.
Holstein.
Ida Grove.
Iowa Falls.
Keokuk.
Kirkman.
Knoxville.
La Porte.
Lake Mills.
Lamoni.
Manson.
Manchester.
Maquoketa.
Marengo.
Marshalltown.
Montezuma.
Missouri Valley.
Monticello.
Mount Pleasant..
Muscatine.
Nevada.
Newton.
Oelwein.
Onawa.
Ottumwa.
Pella.
Pomeroy.
Randolph.
Red Oak.
Reinbeck.
Rock Valley.
Rockwell City.
Sanborn.
Seymour.
Spencer.
Sioux City, High School.
Sioux City, Cathedral School.
Sioux Rapids.
State Center.
Storm Lake.
Story City.
Sumner.
Tama.
Tipton.
Walnut.
Wapello.
Washington.
Waukon.
Waverly.
Woodbine.

No phase of geologic work has greater significance than the preparation of topographic maps. On account of the expense involved the State Geological Survey has, up to the present, not felt justified in entering this field. Considerable wor however, has been done by the United States Geological Sur-

vey in the eastern part of the state. As a result of a conference with officers of the Iowa Geological Survey, the topographic branch of the United States Geological Survey will begin active operations in the central part of the state as well as along the eastern border. In order to aid in the more careful study of the coal resources of Polk county a topographic survey of the area within the Des Moines quadrangle will be completed this summer. Some work will be done also in Fremont county. A line of precise levels will be run between the Mississippi and Missouri rivers, crossing Iowa from east to west through Des Moines. The engineers of the state will be given a fair example of topographic work in a center where engineering enterprises are important, and the measure of their appreciation of this work will be a fair guide for future activity along this line.

The newly organized soil survey at the Iowa State College of Agriculture and Mechanic Arts has found that its reconnaissance work has been satisfactorily done by the Geological Survey in connection with its glacial studies. At the request of Doctor Wilcox, of the Soil Survey, the field assistants of the Geological Survey will continue their observations on soils, and will report more fully on this topic than has been the custom in the past. Similarly, at the request of the State Historical Society and the Iowa Anthropological Society, more complete notes will be made on prehistoric mounds and fortifications.

Volume XV of the regular series of reports is submitted herewith. Papers by Savage, Macbride and Udden, on Benton, Fayette, Emmet, Palo Alto, Pocahontas, Sac, Ida and Clinton counties are included in this volume. Professor Arey of the State Normal School joins the Survey staff for the first time, and presents in this volume an excellent report on Black Hawk county. The report on Jasper county is the work of Mr. Williams. The mineral statistics have been compiled by Doctor Beyer, as usual, and form an essential part of the report.

The second volume of the report on The Grasses of Iowa, prepared by Prof. L. H. Pammel, has just been distributed. It is a work of lasting value, given to the state without cost, except for publication, and even here a portion of the expense for illustrations was borne by the author. The two volumes on The

Grasses of Iowa will long be a standard reference book in schools of higher grade, and form another instance of genuine scientific work which has also an economic value, contributed by this state to an important technical literature. Iowa is not alone in undertaking work of this kind, and it is generally admitted that if it were not for state support of this sort an important element in scientific literature would be lacking.

The correspondence of the State Geologist and of the Assistant Geologist growing out of inquiries from within the state with reference to deposits or finds which are regarded as important by the finders, and from without the state in connection with inquiries from capital seeking investment in connection with Iowa's mineral wealth, has been considerable, and is growing in bulk yearly.

At the request of the state census bureau, the Survey is preparing statements of the mineral output and resources of the state, in text and diagrams, which will appear in connection with the census publications.

The field work for the coming year will be pre-eminently along economic lines. A substantial and wholly necessary foundation for this work has been laid in the earlier stratigraphic studies of the Survey.

FRANK A. WILDER,
Iowa City, Iowa.

REPORT OF ASSISTANT STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1904.

MY DEAR SIR:—I have the honor to submit to you a report upon my work of the past year as follows:

During the months of January and February the time was largely occupied with office duties, in addition to which the report on the Geology of Benton county was completed. An excursion was made into Carroll county for the purpose of studying the drift sections exposed in the cuts recently made along the Chicago Great Western railroad. Some data were collected bearing upon the age and distribution of the loess deposits, and their relation to the drift sheets exposed in this portion of the state.

Search for coal in the southwestern counties of the state has been actively carried on during the past several months. Prospect holes, several hundred feet in depth, have been put down at Tingley in Ringgold county, Carbon in Adams county, and near Creston in Union county. After the drill had penetrated to a considerable depth at each of the above mentioned points, the Survey was requested to send a representative to examine the conditions in that immediate locality, and to advise with regard to a continuance of the work. In none of these drillings were coal seams of workable thickness discovered, but an accurate log of each drilling was made and a definite knowledge of the deeper strata of the Coal Measures in these localities has been obtained.

Notwithstanding the repeated failures that have attended the search for commercial quantities of oil and gas in our state, a company was recently organized for that purpose, and a drill-

ing was made at Coin, in Page county. It is sufficient to say that no oil or gas was found, but a coal seam twenty inches in thickness was encountered at a depth of about two hundred feet.

The writer was called to investigate a gas reservoir that was discovered in putting down a well near the town of Glidden, in Carroll county. The gas-bearing stratum, as at other points in the state, was found to consist of a bed of sand that was enclosed above and below by a sheet of bowlder-bearing clay. The gas that escaped from the pipe showed a good pressure and burned with a strong flame. From indications that were shown in other wells in this neighborhood it seemed probable that the sand bed in which the gas had accumulated extended over a number of square miles. The parties were advised not to form a company with a view of exploiting the gas on a commercial scale, but to pipe it to the town of Glidden, a distance of two and one-half miles, and, without expensive equipment, utilize the gas at home. This has been done and a number of families have been supplied with light and fuel from this source during the last few months.

During August, in company with Dr. S. W. Beyer, an excursion was made for the purpose of studying the distribution of the Iowan drift in the counties of Marshall, Tama, Poweshiek and Jasper, and quite satisfactory conclusions were reached.

The supervision of the illustrating and printing of volume XIV of the Survey reports occupied some months of the year. After that volume was through the press field work was taken up in Fayette county. Notwithstanding necessary interruptions this work was pushed to completion by the early part of December, and the manuscript of the report on the Geology of Fayette County is submitted herewith for publication.

During October work in the field was suspended at your request in order to accompany and assist Mr. John Groves, the representative of the United States Geological Survey, in the collection and shipment to the United States Geological Survey Coal Testing Plant at the World's Fair Grounds, Saint Louis, Missouri, six car loads of coal that had been generously donated by Iowa producers for testing purposes.

Throughout the year the office has looked after a large volume of correspondence relating to the examination of samples and specimens, information with regard to economic deposits and locations, and advice to prospective investors both within and outside of our state. In many cases the sending of printed matter will not furnish the specific information desired, and not infrequently the satisfactory reply to a single communication has involved a search of several hours. In this line of work the survey is enabled to render very practical service to the people of the state; a service that is appreciated as is testified by the numerous letters of thanks which reach this office.

Very respectfully yours,

T. E. Savage,

Assistant State Geologist.

To Prof. Frank A. Wilder,

State Geologist.

MINERAL PRODUCTION IN IOWA
IN 1904

BY

S. W. BEYER.

VALUE OF MINERAL PRODUCTION.

1902.

Coal	$ 8,660,287
Clay	2,843,336
Stone	665,045
Gypsum	337,735
Lead	11,178
Total	$12,517,501

1903.

Coal	$10,439,139
Clay	3,033,583
Stone	597,965
Gypsum	523,008
Lead	8,013
Total	$14,596,708

1904.

Coal	$10,439,496
Clay	3,507,576
Stone	542,170
Gypsum	469,432
Lead	2,619
Sand-lime brick	13,907
Total	$14,975,200

MINERAL PRODUCTION IN IOWA FOR 1904.

BY S. W. BEYER.

The selling value of the mineral products of Iowa for the year 1904 shows a slight gain over that for 1903. The value of the output of clay goods in 1904 was nearly half a million dollars greater than that for the preceding year; coal shows but a

slight increase, while the value of the stone, gypsum and lead production falls a little below that for the year 1903. No zinc or iron was marketed during the year.

The number of producers for the various mineral industries of the state is shown below in parallel columns for the years 1901 to 1904 inclusive.

	1900	1901	1902	1903	1904
Coal	231	242	274	271	269
Clay	381	349	329	296	331
Stone	170	229	273	197	258
Gypsum	7	7	7	8	8
Lead and zinc	6	10	8	8	5
Iron	1	1	......	......	......
Sand-lime brick	.....	.....	......	......	2
Total	796	838	891	780	873

The value of the total mineral production is shown in table No. I.

TABLE No. I.

VALUE OF TOTAL MINERAL PRODUCTION BY COUNTIES FOR 1904.

COUNTIES.	Number of producers.	Total coal.	Total clay.	Total stone.	Miscel-laneous.	Total.
Adair	3		$ 13,335			$ 13,335
Adams	16	$ 29,793	14,378			44,171
Allamakee	3			$ 324		324
Appanoose	57	1,643,684	16,477	520		1,660,681
Audubon	1					
Benton	13		24,425	3,291		27,716
Black Hawk	11		14,753	12,493		27,246
Boone	19	558,999	78,995			637,994
Bremer	1					
Buchanan	1					
Buena Vista	3		17,143			17,143
Butler	1					
Calhoun	6		26,936			26,936
Carroll	1					
Cass	4		116,925			116,925
Cedar	2		14,192	15,824		30,016
Cerro Gordo	6		274,219	50,309		324,528
Cherokee	1					
Chickasaw	1					
Clarke	8			3,186		3,186
Clay	2		43,600			43,600
Clayton	11		13,294	5,875		19,169
Clinton	10		20,325	8,544		28,869
Crawford	2		12,560			12,560
Dallas	16	28,149	131,047	320		159,516
Davis	2	1,332				1,332
Decatur	7		6,625	671		7,296
Delaware	7		12,000	2,809		14,809
Des Moines	12		35,300	18,538		53,838
Dubuque	16		43,700	33,372	$ 2,619	79,691
Emmet	1					
Fayette	11		15,589	10,503		26,092
Floyd	9			4,840		4,840
Fremont	6		14,700			14,700
Greene	8	58,027				58,027
Grundy	2					
Guthrie	8	26,123	22,176			48,299
Hamilton	4		47,350	1,325		48,675
Hancock	1					
Hardin	13		60,234	11,438		71,672
Harrison	6		16,260			16,260
Henry	10		20,619	2,511		23,130
Howard	4			1,267		1,267
Humboldt	3			1,138		1,138

TABLE No. I.—CONTINUED.

VALUE OF TOTAL MINERAL PRODUCTION BY COUNTIES FOR 1904.

COUNTIES.	Number of producers.	Total coal.	Total clay.	Total stone.	Miscellaneous.	Total.
Ida	1	....	....	....	....	....
Iowa	5	....	35,730	....	....	35,730
Jackson	8	....	....	70,475	....	70,475
Jasper	16	374,984	21,050	....	....	396,034
Jefferson	6	20,232	35,017	....	....	55,249
Johnson	10	....	45,710	2,400	....	48,110
Jones	15	....	8,950	82,341	....	91,291
Kossuth	1	....	....	....	....	....
Keokuk	29	67,093	37,682	1,913	....	106,688
Lee	20	....	7,880	31,544	....	39,424
Linn	14	....	39,229	14,377	....	53,606
Louisa	12	278,890	8,381	2,241	....	289,512
Lucas	4	....	....	....	....	....
Madison	7	....	....	43,874	....	43,874
Mahaska	38	954,963	65,080	....	....	1,020,043
Marion	24	431,722	20,875	12,075	....	464,672
Marshall	11	....	59,802	....	....	59,802
Mills	4	....	11,600	....	....	11,600
Mitchell	4	....	....	1,394	....	1,394
Monona	1	....	....	....	....	....
Monroe	12	3,023,883	....	....	....	3,023,883
Montgomery	12	....	47,827	1,410	....	49,237
Muscatine	10	....	32,856	....	....	32,856
Page	9	50,178	43,900	....	....	94,078
Plymouth	2	....	7,900	....	....	7,900
Pocahontas	3	....	77,800	....	....	77,800
Polk	47	1,886,389	648,853	....	....	2,535,242
Pottawattamie	7	....	74,452	....	....	74,452
Poweshiek	3	....	15,738	....	....	15,738
Ringgold	2	....	6,750	....	....	6,750
Sac	2	....	1,180	....	....	1,180
Scott	25	21,448	31,660	40,288	....	93,396
Shelby	1	....	....	....	....	....
Sioux	3	....	13,023	....	....	13,023
Story	3	....	22,306	....	....	22,306
Tama	8	....	98,242	....	....	98,242
Taylor	7	37,838	7,350	....	....	45,188
Union	2	....	21,755	....	....	21,755
Van Buren	11	16,301	3,460	816	....	20,577
Wapello	19	448,474	62,222	30,290	....	540,986
Warren	5	25,182	....	....	....	25,182
Washington	15	....	26,033	5,606	....	31,639
Wayne	12	180,087	11,970	....	....	192,057
Webster	22	275,725	254,930	....	469,432	1,000,087
Winneshiek	2	....	8,000	....	....	8,000
Woodbury	6	....	298,362	....	....	298,362
Wright	5	....	74,665	....	....	74,665
Single producers	..	....	92,199	3,453	....	95,652
Sandstone	26	....	....	8,575	....	8,575
Totals	....	$10,439,496	$ 3,507,576	$ 542,170	$ 472,051	$ 14,975,200

Coal.

The coal production shows a two per cent increase in tonnage and almost no change in total value owing to a corresponding falling off in average price per ton. Of the twenty-three coal producing counties eight only show increased outputs, Monroe county heading the list with a total production exceeding two millions of tons. Keokuk and Lucas counties show the greatest relative shrinkage. Greene, Guthrie, Jefferson, Page, Polk, Wayne and Webster are the remaining counties which increased their production over 1903. Extensive development work was carried on during the year in Lucas, Monroe and Polk counties. The increased production in Monroe county was due largely to the extension of the Consolidation Coal Company.

Table No. II, gives the number of companies producing, distribution of coal, total tons produced, total value, average price per ton, average number of days worked and number of men employed, arranged by counties.

TABLE No. II.

COAL OUTPUT BY COUNTIES FOR 1904.

COUNTIES.	Number of mines.	Tons loaded at mines for shipment.	Sold to local trade or used by employes.	Used at mine for steam and heat.	Total tons produced.	Total selling value at mine.	Average price per ton.	Average number of days worked.	Average number of employes during the year.
Adams	11	....	12,640	10	12,650	$ 29,798	$2.35	131	107
Appanoose	58	824,814	35 167	12,759	872,720	1,643,684	1.88	187	2,769
Boone	18	259,017	20,870	5,770	285,157	558,999	1.96	195	1,029
Dallas	8	6,100	6,400	586	13,086	28,149	2.15	148	44
Davis	1	....	548	....	548	1,332	2.45	150	2
Greene	7	180	26,673	1,360	28,218	58,027	2.05	183	77
Guthrie	5	....	9,149	....	9,149	26,123	2.85	155	40
Jasper	9	236,894	10,894	10,060	257,848	374,984	1.45	217	571
Jefferson	8	1,200	8,360	250	9,810	20,232	2.06	174	28
Keokuk	12	23,269	18,327	2,916	44,512	67,093	1.57	239	118
Lucas	8	163,519	12,117	14,259	189,895	278,890	1.46	184	476
Mahaska	31	607,114	39,048	17,786	663,948	954,963	1.44	197	1,505
Marion	17	296,355	24,695	6,468	327,518	431,722	1.32	225	745
Monroe	12	1,969,217	46,548	46,112	2,061,877	3,023 883	1.46	242	4,118
Page	8	....	17,303	999	18,302	50,178	2 74	235	108
Polk	25	849,540	238,702	42,426	1,130,668	1,886,389	1.67	222	2,136
Scott	7	....	10,594	130	10,724	21,448	1.97	164	51
Taylor	4	8,952	7,286	85	16,278	37,838	2 32	200	63
Van Buren	4	4,721	3,284	....	8,005	16,801	2.08	207	29
Wapello	11	198,875	99,0[illegible]4	4,836	302,355	448,474	1.48	219	585
Warren	5	6,429	5,061	....	11,490	25,182	2.19	149	49
Wayne	7	86,743	12,006	130	98,879	180,087	1.82	203	333
Webster	13	117,363	13,470	3,705	134,538	275,725	2.04	226	345
Total	269	5,659.802	677,2[illegible]6	170.627	6.507 655	$10,489,496	$1.60	218	15,878

The price per ton varies greatly when the different counties are compared, ranging from $1.32 for Marion to $2.85 per ton for Guthrie county. A casual inspection of the aboye table will show that the average price per ton depends very largely upon the disposition of the product. Other things being equal those counties showing the largest local trade report the highest average price per ton. There was a falling off in average number of days work with a more than compensating increase in the number of men employed.

According to the authority of the United States Geological Survey, Iowa ranked ninth in total tonnage, and seventh in total value of coal produced in 1903. The ten leading producers of bituminous coal for 1903 were as follows:

STATE.	TONNAGE.	VALUE.
1. Pennsylvania	$103,117,178	$121,752,759
2. Illinois	36,957,104	43,196,809
3. West Virginia	29,337,241	34,297,019
4. Ohio	24,858,103	31,932,327
5. Alabama	11,654,324	14,246,796
6. Indiana	10,794,692	13,244,817
7. Kentucky	7,538,032	7,979,342
8. Colorado	7,423,602	9,150,943
9. Iowa	6,419,811	10,563,910
10. Kansas	5,839.976	8,871.953

The average price per ton for Iowa during 1903 was $1.65, while for the whole United States it was $1.24.

The production for the state during the past six years was as follows:

YEAR.	TOTAL TONS.	VALUE.	AVERAGE PRICE.	AVERAGE NUMBER DAYS WORKED.	AVERAGE NUMBER MEN EMPLOYED.
1899	5,177,479	6,397,338	$1.24	229	10,971
1900	5,202,939	7,155,341	1.38	228	11,608
1901	5,617,499	7,822,805	1.39	218	12,653
1902	5,904,766	8,660,287	1.47	227	12,434
1903	6,365 233	10,439,139	1.64	232	13,583
1904	6,507,655	10,439.496	1.60	213	15,373

Clay.

Idle yards were, perhaps, no fewer in 1904 than during the preceding year; the increased number reported to be in operation during the latter year was due rather to the opening of new factories. The most notable growth was in the manufacture of drain tile which shows an increase of thirty per cent. The counties showing the greatest gains in this direction are those in or contributary to the area covered by the Wisconsin drift. The growth in the production of tile affected the manufacture of common brick locally but the output of brick for the state does not show a material change. Next to drain tile, the growth in the manufacture of hollow block shows the greatest increase, amounting to about twenty-five per cent. The manufacture of burnt clay ballast fluctuates greatly from year to year and no average figure can be assigned. The total production of clay products shows an increase of about sixteen per cent. The production was distributed as follows:

	1903.		1904.	
	Thousand.	Value.	Thousand.	Value.
Common brick	194,872	$ 1,396,088	207,750	$ 1,430,581
Front brick	7,381	83,306	8,330	101,358
Paving brick	20,688	221,481	15,925	199,528
Ornamental brick	....	1,200	....	972
Fire brick	....	975	20	300
Drain tile	....	1,009,933	....	1,321,745
Sewer pipe	....	88,000	....	94,800
Hollow block	....	131,191	....	164,658
Railway ballast	....	12,000	....	100,000
Pottery	....	55,762	....	66,050
Miscellaneous	....	33,651	....	7,184
Total	....	$ 3,033 583	....	$ 3,507,576

The price of common brick shows a slight falling off while pavers and front brick show a marked increase. The average prices for the principal grades of brick are given below for the two years:

	Iowa.		Whole United States.
	1903.	1904	1903.
Common brick	$ 7 08	$ 6.89	$ 5 97
Front brick	10.60	12 17	12.45
Paving brick	10.62	12 53	9 86

The distribution of clay products by counties, showing the common brick and total brick in thousands, the value of common brick and of total brick, value of drain tile and total value of clay products are shown in table No. III.

TABLE No. III.

CLAY PRODUCTION BY COUNTIES FOR 1904.

COUNTIES.	Number of producers.	COMMON BRICK. Quantity in Thousands	COMMON BRICK. Value.	TOTAL BRICK. Quantity in Thousands	TOTAL BRICK. Value.	DRAIN TILE. Value.	TOTAL VALUE.
Adair	3	1,100	$ 9,000	1,100	$ 9,000	$ 4,185	$ 13,385
Adams	5	1,680	12,660	1,680	12,660	1,718	14,378
Appanoose	2	2,147	16,477	2,147	16,477	....	16,477
Audubon	1	....	....	....	....	....	....
Benton	6	1,365	10,450	1,365	10,450	13,975	24,425
Black Hawk	2	2,340	14,753	2,340	14,753	....	14,753
Boone	6	3,390	23,521	6,983	55,879	20,931	78,995
Bremer	1	....	....	....	....	....	....
Buena Vista	3	165	1,220	165	1,220	15,923	17,143
Butler	1	....	....	....	....	....	....
Calhoun	6	871	6,900	871	6,900	19,256	26,936
Carroll	1	....	....	....	....	....	....
Cass	4	2,020	16,100	2,020	16,100	825	116,925
Cerro Gordo	3	2,888	15,184	2,883	15,184	236,235	274,219
Cherokee	1	....	....	....	....	....	....
Clarke	1	....	....	....	....	....	....
Clay	2	450	3,300	450	3,300	40,000	43,600
Clayton	5	2,093	11,312	2,243	12,512	782	13,294
Clinton	4	2,600	16,175	2,600	16,175	4,150	20,325
Crawford	2	1,750	12,560	1,750	12,560	....	12,560
Dallas	11	2,627	20,064	3,043	24,207	104,765	131,047
Davis	1	....	....	....	....	....	....
Decatur	3	453	3,768	453	3,768	10,424	14,192
Delaware	4	900	6,300	900	6,300	325	16,625
Des Moines	3	2,821	22,435	3,666	30,200	5,100	35,300
Dickinson	3	800	5,600	800	5,600	1,400	12,000
Dubuque	4	6,350	43,700	6,350	43,700	....	43,700
Emmet	1	....	....	....	....	....	....
Fayette	4	1,751	11,329	1,851	12,529	1,560	15,589
Floyd	1	....	....	....	....	....	....
Fremont	6	2,050	13,600	2,175	14,600	....	14,700
Greene	1	....	....	....	....	....	....
Grundy	1	....	....	....	....	....	....
Guthrie	3	503	3,693	503	3,693	18,273	22,176
Hamilton	2	1,185	8,950	1,135	8,950	38,200	47,350
Hancock	1	....	....	....	....	....	....
Hardin	5	1,128	9,760	1,257	12,076	48,018	60,284
Harrison	6	2,280	16,260	2,280	16,260	....	16,260
Henry	6	829	6,805	829	6,805	14,814	20,619
Howard	1	....	....	....	....	....	....
Humboldt	1	....	....	....	....	....	....
Ida	1	....	....	....	....	....	....
Iowa	5	2,990	19,580	2,990	19,580	16,200	35,780

TABLE No. III.—Continued.

CLAY PRODUCTION BY COUNTIES FOR 1904.

COUNTIES.	Number of producers.	COMMON BRICK.		TOTAL BRICK.		DRAIN TILE.	TOTAL VALUE.
		Quantity in Thousands	Value.	Quantity in Thousands	Value.	Value.	
Jackson	1	...	...	...	...	...	...
Jasper	7	1,550	$ 11,550	1,550	$ 11,550	$ 9,500	$ 21,050
Jefferson	8	887	7,099	837	7,099	27,918	35,017
Johnson	8	5,105	34,660	5,105	34,660	11,050	45,710
Jones	2	550	4,150	550	4,150	4,800	8,950
Kossuth	1	...	...	...	...	...	...
Keokuk	8	956	7,688	956	7,688	29,994	37,682
Lee	4	1,365	7,880	1,365	7,880	...	7,880
Linn	8	8,968	28,104	8,968	28,104	11,125	39,229
Louisa	3	554	8,831	554	8,881	4,500	8,381
Lucas	1	...	...	...	...	...	...
Madison	1	...	...	...	...	...	...
Mahaska	6	8,406	24,051	5,495	47,030	15,050	65,080
Marion	4	1,000	7,175	1 000	7,175	13,800	20,875
Marshall	10	3,946	24,400	4,196	26,650	23,052	59,802
Mills	4	1,500	11,600	1,500	11,600	...	11,600
Monona	1	...	...	...	...	...	...
Montgomery	8	4,938	39,048	4,958	39,348	8,079	47,827
Muscatine	10	4,285	26,272	4,285	26,272	...	32,856
Page	6	4,129	29,900	4,129	29,900	14,000	43,900
Plymouth	2	1,150	7,900	1,150	7,900	...	7,900
Pocahontas	2	550	3,950	550	3,950	73,850	77,800
Polk	22	26,110	194,194	40,808	359,116	181,857	648,853
Pottawattamie	7	10,979	73,492	10,979	73,492	960	74,452
Poweshiek	3	730	6,015	730	6,015	9,539	15,738
Ringgold	2	675	5,250	675	5,250	1,500	6,750
Sac	2	160	1,180	160	1,180	...	1,180
Scott	5	3,116	21,660	3,616	21,660	8,500	31,660
Shelby	1	...	...	...	...	...	...
Sioux	3	1,830	18,028	1,830	18,028	...	18,028
Story	8	275	2,200	550	4,900	17,406	22,306
Tama	7	5,893	41,284	8,621	68,267	29,975	98,242
Taylor	3	740	5,550	740	5,550	1,800	7,850
Union	2	2,195	16,865	2,195	16,865	8,975	21,755
Van Buren	3	550	3,460	550	3,460	...	3,460
Wapello	3	6,502	41,819	6,502	41,819	17,868	62,222
Washington	6	1,597	11,230	1,597	11,230	14,803	26,033
Wayne	5	1,695	11,970	1,693	11,970	...	11,970
Webster	9	10,186	64,770	11,236	78,930	112,874	254,930
Winneshiek	2	1,200	8,000	1,200	8,000	...	8,000
Woodbury	6	35,365	229,812	36,831	244,094	15,450	298,362
Wright	5	935	8,765	935	8,765	65,900	74,665
Single producers	21	6,847	49,828	6,847	49,828	41,311	92,199
Totals	331	207,750	$ 1,430,581	282,005	$ 1,732,639	$ 1,321,745	$3,507,576

According to the United States Geological Survey, Iowa ranked eighth in production of clay products for 1903, producing 2.88 per cent of the entire output of the country; she ranked eighth in the manufacture of paving brick, third in building block, being exceeded by Ohio and Indiana, and second in drain tile, surpassed by Ohio alone. For the year 1904 Iowa probably heads the list of drain tile producers. The ten leading clay producers for 1903 were as follows.

RANK	STATE.	NUMBER OF PRODUCING FIRMS REPORTING.	COMMON BRICK	PAVING BRICK	DRAIN TILE	TOTAL CLAY
1	Ohio........	815	$ 3,002,506	$ 1,860,071	$ 1,149,990	$25,208,124
2	Pennsylvania	523	6,174,437	685,274	11,451	18,847,324
3	New Jersey..	159	1,500,295	22,195	20,825	13,416,939
4	Illinois	502	5,388,589	1,015,710	892,807	11,190,797
5	New York..	242	5,305,522	220,296	140,181	9,208,252
6	Indiana	490	1,697,190	482,967	1,014,706	5,694,625
7	Missouri.....	242	1,725,253	307,237	45,363	5,661,607
8	Iowa	304	1,355,129	232,510	1,028,383	3,093,403
9	California ...	105	1,600,882	....	17,994	2,831,543
10	West Virginia	56	576,404	576,258	1,499	2,558,560

The production of clay products shows a satisfactory growth during the past five years. The leading products showing such growth are given in the table herewith.

YEAR.	COMMON BRICK.	TOTAL BRICK	DRAIN TILE.	POTTERY.	TOTAL.
1900	$ 1,386,641	$ 1,621,604	$ 377,586	$31,339	$2,291,251
1901	1,611,040	1,944,351	534,935	26,200	2,737,825
1902	1,575,959	1,891,366	672,212	43,387	2,843,336
1903	1,396,088	1,703,050	1,009,933	55,762	3,033,583
1904	1,430,581	1,732,719	1,321,745	66,050	3,507,576

Up to 1904 the substitutes for brick, sand-lime brick and cement block, do not appear to have seriously affected the demand for common building brick.

Stone.

The stone industry for 1904 shows a decline as compared with the preceding year. The greatest shrinkages appear in the production of building stone and lime. The amount of crushed stone produced shows a satisfactory increase. Up-to-date crushing plants were established during the year at a number of points, and an increased production in this line may be expected for 1905. The production for 1904 was distributed as follows:

LIMESTONE USED FOR:	VALUE 1904.	VALUE 1903.
Building purposes	$162,577	$204,769
Flagging and curbing	8,970	13,793
Lime	91,008	113,195
Crushed stone		
Road making	53,082	63,637
Railway ballast	5,549	12,243
Concrete	97,274	68,763
Rubble and riprap	113,568	102,403
Miscellaneous	1,565	2,158
Sandstone	8,575	17,008
Total stone	$542,168	$597,965

Imported limes and greatly cheapened Portland cement are the chief contributory causes for the falling off in the production of domestic limes. Table No. IV gives the production of limestone by counties and specifies the various grades of stone put upon the market.

TABLE No. IV.

PRODUCTION OF LIMESTONE BY COUNTIES FOR 1904.

COUNTIES.	Number of producers.	Building.	Flagging and curbing.	Lime.	Road making.	Railway ballast and concrete.	Rubble and riprap.	Miscellaneous.	Total.
Allamakee	3	$ 260	$ 64	....	....	....	....	....	$ 324
Appanoose	2	60	10	....	....	....	$ 450	....	520
Benton	7	1,169	....	$ 1,920	....	....	187	$ 15	3,291
Black Hawk	9	8,416	180	....	$ 2,873	$ 250	774	....	12,493
Buchanan	1	....	....	....	....	....	....	....	....
Cedar	2	400	....	....	4,887	....	10,537	....	15,824
Cerro Gordo	4	13,700	100	2,600	....	33,684	225	....	50,309
Chickasaw	1	....	....	....	....	....	....	....	....
Clarke	7	2,368	198	....	....	....	540	80	3,186
Clayton	7	2,658	2,383	150	380	170	134	....	5,875
Clinton	6	3,870	70	....	3,330	900	374	....	8,544
Dallas	2	320	....	....	....	....	....	....	320
Decatur	3	321	10	....	340	....	....	....	671
Delaware	4	2,235	399	....	....	....	175	....	2,809
Des Moines	9	6,406	60	....	2,480	1,711	7,879	....	18,538
Dubuque	12	16,160	79	8,438	380	6,968	1,347	....	33,372
Fayette	7	8,358	950	350	....	....	845	....	10,503
Floyd	8	3,665	600	....	100	225	....	250	4,840
Grundy	1	....	....	....	....	....	....	....	....
Hamilton	2	....	....	....	....	....	1,325	....	1,325
Hardin	8	4,965	....	....	1,859	2,964	1,650	....	11,438
Henry	4	1,110	....	....	100	1,301	....	....	2,511
Howard	3	675	....	....	582	10	....	....	1,267
Humboldt	2	1,078	....	....	....	....	60	....	1,138
Jackson	7	265	....	69,550	660	....	....	....	70,475
Johnson	2	800	....	....	1,040	....	560	....	2,400
Jones	13	33,740	219	....	885	9,842	37,655	....	82,341
Keokuk	8	1,897	10	....	....	....	6	....	1,913
Lee	16	6,391	3,195	....	7,966	5,699	7,293	1,000	31,544

TABLE No. IV—CONTINUED.

COUNTIES.	Number of producers.	Building.	Flagging and curbing.	Lime	Road making.	Railway ballast and concrete.	Rubble and riprap.	Miscellaneous.	Total.
Linn	6	$ 1,235		$ 8,000		$ 2,379	$ 2,763		$ 14,377
Louisa	9	2,141	$ 47		$ 48		5		2,241
Madison	7	13,794	10		17,862	12,065	123	$ 20	43,874
Mahaska	1								
Marion	3	2,850	25				9,000	200	12,075
Marshall	1								
Mitchell	5	1,394							1,394
Montgomery	5	1,260					150		1,410
Pocahontas	3								
Scott	13	10,691	75		4,075	19,492	5,955		40,288
Tama	1								
Van Buren	4	780	36						816
Wapello	5	1,687			3,225	8,138	20,240		30,290
Washington	9	4,613	130			25	838		5,606
Single producers		845	120		10		2,478		3,453
Total	232	$ 162,577	$ 8,970	$ 91,008	$ 53,082	$ 102,823	$ 113,568	$ 1.565	$ 533,593

Fourteen counties with twenty-six producers report sandstone but the total production was insignificant, amounting to $8,575, and used mainly for building purposes and as rubble. Jones county still leads in the production of stone while Jackson is the ranking producer for lime. The table below shows the status of the stone industry for Iowa during the past six years:

YEAR.	LIMESTONE.				SAND-STONE.	TOTAL STONE.
	BUILDING.	LIME.	CRUSHED STONE.	RUBBLE AND RIPRAP.		
1899	$312,595	$102,611	$ 158,917	$ 139,064	$ 24,348	$ 809,924
1900	248,833	110,589	153 920	58,493	19,063	605,473
1901	272,501	221,760	183,902	85,342	14,341	791,827
1902	195,009	114,051	153,372	176 927	15,061	665,018
1903	204,769	113,195	144,643	102,403	17,008	597,965
1904	162,577	91,008	153,372	113,568	8,575	542,165

Gypsum.

The gypsum production for 1904 shows a considerable shrinkage in gross tonnage and total value. The gross output of crude gypsum for the year was reported to be 145,359; was valued at $92,033, or a falling off of about 15 per cent. In the table below is given the distribution of the product as compared with 1903:

	1903.		1904.	
	TONS.	VALUE.	TONS.	VALUE.
Wall or cement plaster	87,397	$411,503	94,811	$ 399,281
Plaster of Paris	30,306	100,744	19,540	64,112
Land plaster	2,098	9,227	933	1,816
Crude gypsum	703	1,534	2,013	4,223
Total	120,504	$523,008	117,297	$ 469,432

Lead and Zinc.

As during the preceding year, no zinc ore produced in Iowa was marketed. A small quantity of "dry bone" was produced, incidental to development work, but was not put upon the market.

The production of lead for 1904 shows a decline notwithstanding the earlier reports to the contrary. The local smelter purchased the entire output of the state which was confined to Dubuque county. The production for the year was about 97,000 pounds valued at $2,619.

Sand-Lime Brick.

The sand-lime brick industry is of recent growth in this country. The first plant was built at Michigan City, Indiana, early in 1901 and put in operation during that year. In 1902 there were twenty plants in existence and according to the United States Geological Survey 6,000,000 brick were actually sold during that year. In 1903 it is estimated that seventy plants were in operation in twenty-nine states, with an output of 20,000,000 brick. One plant only was credited to Iowa, the Iowa Granite Brick Company at Clinton. A second plant was installed and put in operation at Cedar Rapids during 1904. The total sales for 1904 were as follows:

Brick, 1,962,000, amounting to $13,907.

Iron.

No iron produced in Iowa was marketed during 1904. The mine in the vicinity of Waukon, in Allamakee county, is still without transportation which would warrant its operation.

Cement Block Industry.

The manufacture of cement block, as in the case of the manufacture of sand-lime brick, is a new industry for the state. The statistics obtained are very imperfect owing to the newness of the industry and the difficulty of securing complete returns. Thirty-eight factories reported sales for 1904. Many additional factories were installed during the year but opened too late in the season to put their product upon the market. It is believed that the report for 1905 will show the number of producing plants to more than double, and the output quadruple. The returns received for 1904 are given below.

Cement block, square feet in wall	442,343	$83,701
Caps and sills, linear feet	9,223	3,068
Flue linings, linear feet	865	174
Cement posts	762	188
Sand-cement brick	42,000	400
Porch piers	400	100
Total		$87,631

CEMENT AND CEMENT MATERIALS OF IOWA.

BY

EDWIN C. ECKEL AND H. F. BAIN.

CEMENT AND CEMENT MATERIALS OF OWA.

BY EDWIN C. ECKEL AND H. F. BAIN.

CONTENTS.

INTRODUCTION.

BY H. FOSTER BAIN.

Cement is now one of the most important mineral resources of the United States. In the value of the annual output it ranks thirteenth. It is about equal to the zinc production if the latter be estimated at New York prices. The rapid increase in use, and growth of local production of cement in the last ten years have been among the most striking features of the American mineral industry. The following tables from the mineral resources for 1902, as prepared by L. L. Kimball of the United States Geological Survey, will give some idea of the present extent of the industry.

PRODUCTION OF CEMENT IN THE UNITED STATES.

The total production of hydraulic cement in the United States for 1902 was 25,753,504 barrels, an increase of 5,684,767 barrels over the quantity produced during the preceding year. The value of this production was $25,366,380.

Of the entire quantity, 17,230,644 barrels were Portland, valued at $20,864,078; 8,044,305 barrels were natural-rock, valued at $4,076,630, and 478,555 barrels were Pozzuolana or slag cement, valued at $425,672.

The growth of the cement industry is indicated by the fact that, although the increase in production for 1901 over 1900 reached the large number of 2,837,587 barrels, the increase in production for 1902 over 1901 was 5,684,767 barrels. It is of interest here to note that in 1892, just ten years ago, the entire production of cement in the United States was but 8,758,621 barrels, of which 8,211,181 barrels were natural-rock and 547,440 barrels were Portland.

Pennsylvania holds leading place as a producer of Portland cement, while New Jersey follows in second place. The counties of Lehigh and Northampton, Pennsylvania, formerly

included all the factories producing Portland cement in the state; now, although they are still the center of that industry, there are five plants in other counties, none of them, however, ranking at present among the very large producers. Under all other sections is included the production of Alabama, California, Colorado, Georgia, Illinois, Indiana, Kansas, Missouri, South Dakota, Texas, Utah and Virginia.

RELATION OF DOMESTIC PRODUCTION AND CONSUMPTION TO IMPORTS.

The increase, both in the use and in the production of Portland cement in the United States within the last thirteen years, as compared with natural-rock cement and with imported cement, is shown in the following table:

Comparative production of Portland and of natural-rock cement in the United States and of imports of hydraulic cement, 1890—1902.

Year.	Natural cement.	Portland cement.	Total of natural and Portland cement.	Imports.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*
1890	7,082,204	335,500	7,417,704	1,940,186
1893	7,411,815	590,652	8,002,467	2,674,149
1895	7,741,077	990,324	8,731,401	2,997,395
1897	8,311,688	2,677,775	10,989,463	2,090,924
1899	9,868,179	5,652,266	15,520,445	2,108,388
1900	8,383,519	8,482,020	16,865,539	2,386,683
1901	7,084,828	12,711,225	19,796,048	939,330
1902	8,044,305	17,230,644	25,274,949	1,961,013

This table does not include the production of Pozzuolana or slag cement reported by this bureau for the last three years, which is as follows: 1900, 365,611 barrels; 1901, 272,689 barrels; 1902, 478,555 barrels.

Following is a diagram showing the growth of the domestic production of Portland cement, the increase of total consumption of Portland cement, and the decline of the imports of foreign hydraulic cements during the last thirteen years.

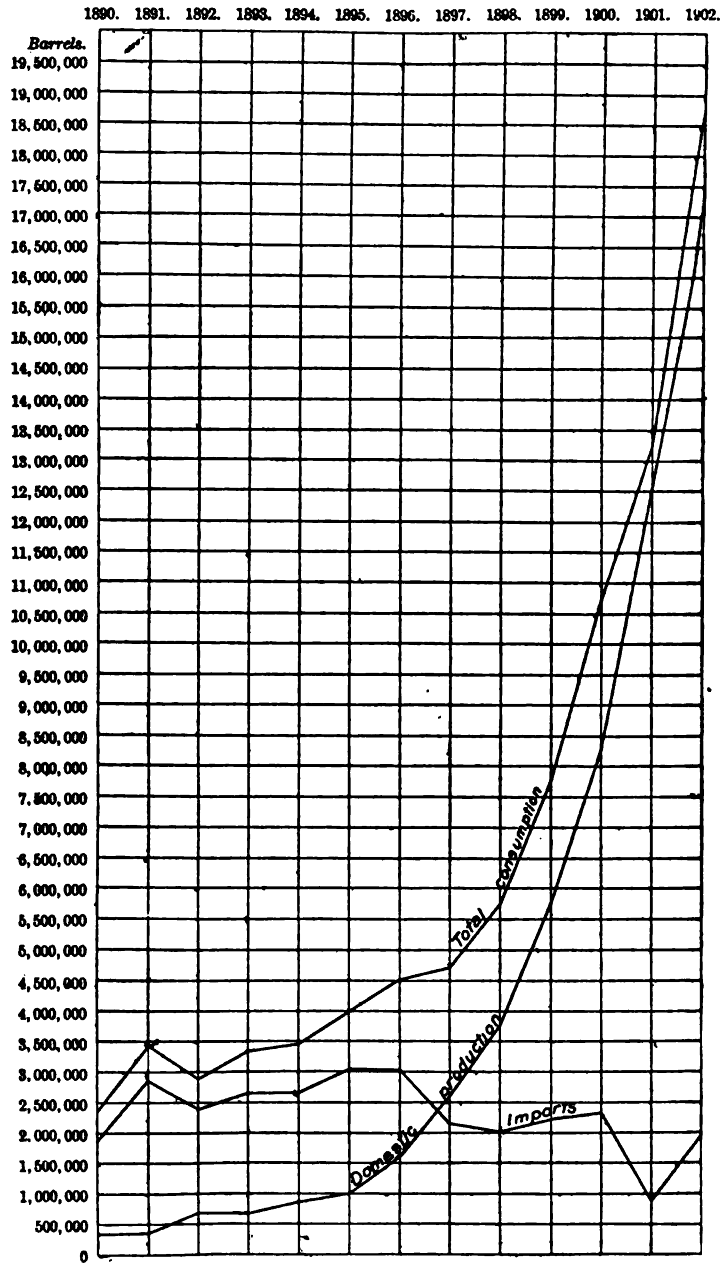


PLATE 2.—Diagram showing the relation of domestic production of Portland cement to imports and to total consumption of Portland cement in the United States, by years and by barrels, from 1890 to 1902, inclusive.

USES OF CEMENT.

The increased use of Portland cement has quite kept pace with its larger production. It is constantly being used in new situations, as well as being substituted for cementing materials. It is now very largely used in the place of lime or other mortars in ordinary wall construction. Immense quantities are used in concrete work for foundations of all kinds and, lately, for concrete, and steel and concrete construction of walls. It is made up into artificial building blocks and is being used experimentally for fence posts and railway ties. In the western states the railways afford the largest market, since culverts and bridge abutments of all kinds are now largely made of it. It has many minor and novel uses.

SCOPE OF THIS REPORT.

The present report is the outgrowth of work taken up by the writer in 1899 and 1900 while serving as Assistant State Geologist of Iowa. At that time material was collected from the most promising localities and a series of analyses and tests were undertaken by Mr. A. E. Lundteigen, who was at that time connected with the Western Portland Cement Company, and later with the Peerless Portland Cement Company. Mr. Lundteigen's results, a portion of which are herewith published, were most encouraging, but the series was not completed, and, pending their completion, it was thought better to make no publication.

In 1903 Mr. E. C. Eckel, of the United States Geological Survey, undertook the preparation for that organization of a special report upon the cement materials of the United States, and it was decided that so far as relates to Iowa the work should be done in co-operation between the Federal and the State Survey. The present report is the result. In this Mr. Eckel discusses the general nature of the materials and processes employed in the manufacture of Portland cement, and the writer gives a brief discussion of the materials available in Iowa. For details as to local geology the reader is referred to the various county reports already published, and for data regarding limes and natural cement rock, he is referred to the

same source. The attempt has been made to indicate somewhat generally the distribution of the materials available, and specifically the nature of these materials. In order that intending manufacturers may have as full a comprehension of the cement industry as possible, Mr. Eckel has discussed not only materials available in Iowa, but those which may be used in competition with any local plant.

THE MATERIALS AND MANUFACTURE OF PORTLAND CEMENT.*

BY EDWIN C. ECKEL.

The Relation of Portland to Other Cements.

It seems desirable, before taking up the specific subject of Portland cement, to indicate the relationships existing between Portland and other cementing materials. These relationships, both as regards resemblances and differences, seem to be best brought out by the classification presented below. This grouping is based primarily upon the amount of chemical change caused by the processes of manufacture and use; and secondarily upon the chemical composition of the cement after setting. As regard is paid to both technologic and commercial considerations, it would seem to be a fairly satisfactory working classification.

GROUP I. SIMPLE CEMENTS.

Simple Cements include all those cementing materials produced by the expulsion of a liquid or gas from the raw material; and whose setting properties are due to the simple reabsorption of the same liquid or gas and the reassumption of the original composition; the set cement being therefore similar in composition to the raw material.

NOTE.—The paper on the raw materials and methods of manufacture of Portland cement has been prepared as the result of field work and other investigations carried on by the writer for the United States Geological Survey. Certain sections of the contribution have appeared, in slightly different form, in "Municipal Engineering" during the past two years.

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Sub-group I a. Hydrate Cements; setting properties due to reabsorption of water.

Sub-group I b. Carbonate Cements; setting properties due to reabsorption of carbon dioxide.

GROUP II. COMPLEX CEMENTS.

Complex cements include all those cementing materials whose setting properties are due to the action of entirely new chemical compounds which were formed during manufacture or use; the set cement being therefore different in composition from the raw material.

Sub-group II a. Silicate Cements; setting properties due largely to the formation of silicates.

Sub-group II b. Oxychloride Cements; setting properties due to the formation of oxychlorides.

GROUP I. SIMPLE CEMENTS.

The cementing materials included in the present group are those known commercially as "plasters," "hard-finishing cements" and "limes."

The material from which the "plasters" and "hard-finishing cements" are derived is gypsum, a hydrous calcium sulphate; while the limes are derived from limestone, which is essentially calcium carbonate, though usually accompanied by greater or less amounts of magnesium carbonate.

On heating gypsum to a certain temperature, the raw material parts readily with much of its water, leaving an almost anhydrous calcium sulphate, known commercially as plaster of Paris. On exposing this plaster to water, it re-hydrates, and again takes the composition of the gypsum from which it was derived.

In like manner limestone, on being sufficiently heated, gives off its carbon dioxide, leaving calcium oxide or "quicklime." This, on exposure to moisture and air carrying carbon dioxide, reabsorbs carbon dioxide and reassumes its original composition, calcium carbonate.

The cementing materials included in this group, therefore, while differing in composition and properties, agree in certain important points. They are all manufactured by heating a

natural raw material sufficiently to remove much or all of its water or carbon dioxide; and, in all, the setting properties of the cementing material are due to the fact that, on exposure to the water or carbon dioxide which has thus been driven off, the cement reabsorbs the previously expelled liquid or gas, and reassumes the chemical composition of the raw material from which it was derived.

Plaster of Paris, after setting, is not chemically different from the gypsum from which it was derived; while if the sand, added to avoid shrinkage, be disregarded, hardened lime mortar is nothing more or less than an artificial limestone.

SUB-GROUP I a. HYDRATE CEMENTS.

The materials here included are known in commerce as "plaster of Paris," "Cement plaster," "Keene's cement," "Parian cement," etc. All of these hydrate cements are based upon one raw material, gypsum. The partial dehydration of pure gypsum produces plaster of Paris. By the addition to gypsum, either by nature or during manufacture, of relatively small amounts of other materials; or by slight variations in the processes of manufacture, the time of setting, hardness, and other important technical properties of the resulting plaster can be changed to a sufficient degree to warrant separate naming and descriptions of the products.

Both the technology and the chemistry of the processes involved in the manufacture of the hydrate cements are simple. The mineral gypsum, when pure, is a hydrous sulphate of lime, of the formula $CaSO_4$, $2H_2O$, corresponding to the composition calcium sulphate 79.1 per cent, water 20.9 per cent. As noted later (under the head of Cement Plasters) gypsum, as mined, rarely even approximates to this ideal composition, its impurities often amounting to 25 per cent or even more. These impurities, chiefly clayey materials and fragments of quartz and limestone, often exercise an appreciable effect upon the properties of the plaster resulting from burning such impure gypsum.

SUB-GROUP I b. CARBONATE CEMENTS.

The cementing materials falling in the present sub-group are oxides, derived from natural carbonates by the application of heat. On exposure, under proper conditions, to any source of carbon dioxide, the cementing material recarbonates and "sets." In practice the carbon dioxide required for setting is obtained simply by exposure of the mortar to the air. In consequence the set of these carbonate cements, as commonly used, is very slow (owing to the small amount of carbon dioxide which can be taken up from ordinary air); and, what is more important from an engineering point of view, none of the mortar in the interior of a wall ever acquires hardness, as only the exposed portions have an opportunity to absorb carbon dioxide. From the examination of old mortars it has been thought probable that a certain amount of chemical action takes place between the sand and the lime, resulting in the formation of lime silicates; but this effect is slight and of little engineering importance compared with the hardening which occurs in consequence of the reabsorption of carbon dioxide from the air.

Limestone is the natural raw material whose calcination furnishes the cementing materials of this group. If the limestone be an almost pure calcium carbonate it will, on calcination, yield calcium oxide or "quicklime." If, however, the limestone should contain any appreciable percentage of magnesium carbonate, the product will be a mixture of the oxides of calcium and magnesium, commercially known as magnesian lime. A brief sketch of the mineralogic relationships of the various kinds of limestone, in connection with the chemistry of lime burning will be of service at this point of the discussion.

Pure limestone has the composition of the mineral calcite, whose formula is ($CaCO_3$), corresponding to the composition calcium oxide 56 per cent; carbon dioxide, 44 per cent. In the magnesian limestones part of this calcium carbonate is replaced by magnesium carbonate, the resulting rock therefore having a formula of the type ($x\,CaCO_3$), ($y\,MgCO_3$). This replacement may reach the point at which the rock has the composition of the mineral dolomite, an equal mixture of the two carbonates, with the formula ($CaCO_3$),($MgCO_3$),corresponding to the composi-

tion calcium oxide, 30.44 per cent; magnesium oxide, 21.74 per cent; carbon dioxide, 44.22 per cent. Limestones may, therefore, occur with any intermediate amount of magnesium carbonate, and the lime which they produce on calcination will carry corresponding percentages of magnesium oxide, from 0 per cent to 21.74 per cent. Commercially those limes which carry less than 10 per cent of magnesium oxide are, for building purposes, marketable as "pure limes", while those carrying more than that percentage will show sufficiently different properties to necessitate being marketed as "magnesian limes."

Aside from the question of magnesia, a limestone may contain a greater or lesser amount of impurities. Of these the most important are silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3). These impurities, if present in sufficient quantity, will materially affect the properties of the lime produced, as will be noted later under the heads of Hydraulic Limes and Natural Cements.

The carbonate cements may be divided into two classes—

(1) High calcium limes;
(2) Magnesian limes.

High Calcium Limes.—On heating a relatively pure carbonate of lime to a sufficiently high degree, its carbon dioxide is driven off, leaving calcium oxide (CaO) or "quicklime." Under ordinary conditions, the expulsion of the carbon dioxide is not perfectly effected until a temperature of 925° C. is reached. The process is greatly facilitated by blowing air through the kiln, or by the injection of steam. On treating quicklime with water, "slaking" occurs, heat being given off, and the hydrated calcium oxide (CaH_2O_2) being formed. The hydrated oxide will, upon exposure to the atmosphere, slowly reabsorb sufficient carbon dioxide to reassume its original composition as lime carbonate. As this reabsorption can take place only at points where the mortar is exposed to the air, the material in the middle of thick walls never becomes recarbonated. In order to counteract the shrinkage which would otherwise take place during the drying of the mortar, sand is invariably added in the preparation of lime mortars, and as noted above, it is probable that certain reactions take place between the lime and the

sand. Such reactions, however, though possibly contributing somewhat to the hardness of old mortars, are only incidental and subsidiary to the principal cause of setting, recarbonation. The presence of impurities in the original limestone affects the character and value of the lime produced. Of these impurities, the presence of silica and alumina in sufficient quantities will give hydraulic properties to the resulting limes; such materials will be discussed in the next group as Hydraulic Limes and Natural Cements.

Magnesian Limes.—The presence of any considerable amount of magnesium carbonate in the limestone from which a lime is obtained has a noticeable effect upon the character of the product. If burned at the temperature usual for a pure limestone, magnesian limestones give a lime which slakes slowly without evolving much heat, expands less in slaking, and sets more rapidly than pure lime. To this class belong the well known and much used limes of Canaan (Conn.); Tuckahoe, Pleasantville and Ossining (N. Y.); various localities in New Jersey and Ohio; and Cedar Hollow (Penn.). Magnesian limes are made at a number of points in Iowa, including Dubuque, Lime City, Cedar Valley and other points.* Under certain conditions of burning, pure magnesian limestones yield hydraulic products, but in this case, as in the case of the product obtained by burning pure magnesite, the set seems to be due to the formation of a hydroxide rather than of a carbonate. Magnesian limestones carrying sufficient silica and alumina will give, on burning, a hydraulic cement falling in the next group under the head of Natural Cements.

GROUP II. COMPLEX CEMENTS.

The cementing materials grouped here as Silicate or Hydraulic Cements include all those materials whose setting properties are due to the formation of new compounds, during manufacture or use, and not to the mere reassumption of the original composition of the material from which the cement was made. These new compounds may be formed either by chemical change during manufacture or by chemical interac-

*See Houser, G. L., Iowa Geological Survey, Vol. I, pp. 199-207, 1898. Calvin and Bain, Ibid., Vol. X, pp. 601-604, 1900.

tion, in use, of materials which have merely been mechanically mixed during manufacture.

In the class of silicate cements are included all the materials commonly known as cements by the engineer (natural cements, Portland cement, pozzuolanic cements), together with the hydraulic limes.

Though differing widely in raw material, methods of manufacture and properties, the silicate cements agree in two prominent features; they are all hydraulic (though in very different degrees); and this property of hydraulicity is, in all, due largely or entirely to the formation of tri-calcic silicate ($3\,CaO, SiO_2$). Other silicates of lime, as well as silico-aluminates, may also be formed; but they are relatively unimportant, except in certain of the natural cements and hydraulic limes where the lime-aluminates may be of greater importance than is here indicated. This will be recurred to in discussing the groups named.

The silicate cements are divisible, on technologic grounds, into four distinct classes. The basis for this division is given below. It will be seen that the first named of these classes (the pozzuolanic cements) differs from the other three very markedly, inasmuch as its raw materials are not calcined after mixture; while in the last three classes the raw materials are invariably calcined after mixture. The four classes differ somewhat in composition but more markedly in methods of manufacture and in the properties of the finished cements.

CLASSES OF SILICATE CEMENTS.

1. *Pozzuolanic or Puzzolan Cements;* produced by the mechanical mixture, without calcination, of slaked lime and a silico-aluminous material (the latter being usually a volcanic ash or blast-furnace slag).

2. *Hydraulic Limes;* produced by the calcination, at a temperature not much higher than that of decarbonation, of a siliceous limestone so high in lime carbonate that a considerable amount of free lime appears in the finished product.

3. *Natural Cements;* produced by the calcination, at a temperature between those of decarbonation and clinkering, of a siliceous limestone (which may also carry notable amounts of alumina and of magnesium carbonate) in which the lime ca-

included all the factories producing Portland cement in the state; now, although they are still the center of that industry, there are five plants in other counties, none of them, however, ranking at present among the very large producers. Under all other sections is included the production of Alabama, California, Colorado, Georgia, Illinois, Indiana, Kansas, Missouri, South Dakota, Texas, Utah and Virginia.

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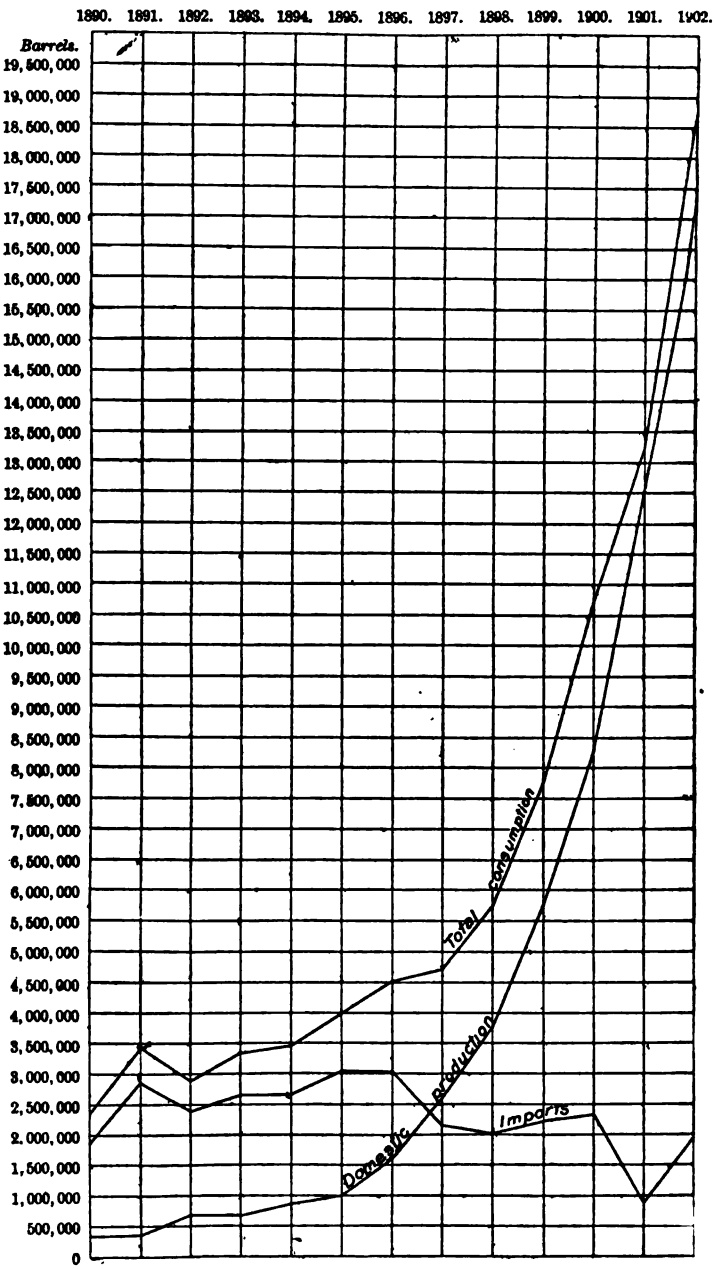

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USES OF CEMENT.

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BY EDWIN C. ECKEL.

The Relation of Portland to Other Cements.

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GROUP I. SIMPLE CEMENTS.

Simple Cements include all those cementing materials produced by the expulsion of a liquid or gas from the raw material; and whose setting properties are due to the simple reabsorption of the same liquid or gas and the reassumption of the original composition; the set cement being therefore similar in composition to the raw material.

NOTE.—The paper on the raw materials and methods of manufacture of Portland cement has been prepared as the result of field work and other investigations carried on by the writer for the United States Geological Survey. Certain sections of the contribution have appeared, in slightly different form, in "Municipal Engineering" during the past two years.

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Sub-group I a. Hydrate Cements; setting properties due to reabsorption of water.

Sub-group I b. Carbonate Cements; setting properties due to reabsorption of carbon dioxide.

GROUP II. COMPLEX CEMENTS.

Complex cements include all those cementing materials whose setting properties are due to the action of entirely new chemical compounds which were formed during manufacture or use; the set cement being therefore different in composition from the raw material.

Sub-group II a. Silicate Cements; setting properties due largely to the formation of silicates.

Sub-group II b. Oxychloride Cements; setting properties due to the formation of oxychlorides.

GROUP I. SIMPLE CEMENTS.

The cementing materials included in the present group are those known commercially as "plasters," "hard-finishing cements" and "limes."

The material from which the "plasters" and "hard-finishing cements" are derived is gypsum, a hydrous calcium sulphate; while the limes are derived from limestone, which is essentially calcium carbonate, though usually accompanied by greater or less amounts of magnesium carbonate.

On heating gypsum to a certain temperature, the raw material parts readily with much of its water, leaving an almost anhydrous calcium sulphate, known commercially as plaster of Paris. On exposing this plaster to water, it re-hydrates, and again takes the composition of the gypsum from which it was derived.

In like manner limestone, on being sufficiently heated, gives off its carbon dioxide, leaving calcium oxide or "quicklime." This, on exposure to moisture and air carrying carbon dioxide, reabsorbs carbon dioxide and reassumes its original composition, calcium carbonate.

The cementing materials included in this group, therefore, while differing in composition and properties, agree in certain important points. They are all manufactured by heating a

natural raw material sufficiently to remove much or all of its water or carbon dioxide; and, in all, the setting properties of the cementing material are due to the fact that, on exposure to the water or carbon dioxide which has thus been driven off, the cement reabsorbs the previously expelled liquid or gas, and reassumes the chemical composition of the raw material from which it was derived.

Plaster of Paris, after setting, is not chemically different from the gypsum from which it was derived; while if the sand, added to avoid shrinkage, be disregarded, hardened lime mortar is nothing more or less than an artificial limestone.

SUB-GROUP I a. HYDRATE CEMENTS.

The materials here included are known in commerce as "plaster of Paris," "Cement plaster," "Keene's cement," "Parian cement," etc. All of these hydrate cements are based upon one raw material, gypsum. The partial dehydration of pure gypsum produces plaster of Paris. By the addition to gypsum, either by nature or during manufacture, of relatively small amounts of other materials; or by slight variations in the processes of manufacture, the time of setting, hardness, and other important technical properties of the resulting plaster can be changed to a sufficient degree to warrant separate naming and descriptions of the products.

Both the technology and the chemistry of the processes involved in the manufacture of the hydrate cements are simple. The mineral gypsum, when pure, is a hydrous sulphate of lime, of the formula $CaSO_4, 2H_2O$, corresponding to the composition calcium sulphate 79.1 per cent, water 20.9 per cent. As noted later (under the head of Cement Plasters) gypsum, as mined, rarely even approximates to this ideal composition, its impurities often amounting to 25 per cent or even more. These impurities, chiefly clayey materials and fragments of quartz and limestone, often exercise an appreciable effect upon the properties of the plaster resulting from burning such impure gypsum.

SUB-GROUP I b. CARBONATE CEMENTS.

The cementing materials falling in the present sub-group are oxides, derived from natural carbonates by the application of heat. On exposure, under proper conditions, to any source of carbon dioxide, the cementing material recarbonates and "sets." In practice the carbon dioxide required for setting is obtained simply by exposure of the mortar to the air. In consequence the set of these carbonate cements, as commonly used, is very slow (owing to the small amount of carbon dioxide which can be taken up from ordinary air); and, what is more important from an engineering point of view, none of the mortar in the interior of a wall ever acquires hardness, as only the exposed portions have an opportunity to absorb carbon dioxide. From the examination of old mortars it has been thought probable that a certain amount of chemical action takes place between the sand and the lime, resulting in the formation of lime silicates; but this effect is slight and of little engineering importance compared with the hardening which occurs in consequence of the reabsorption of carbon dioxide from the air.

Limestone is the natural raw material whose calcination furnishes the cementing materials of this group. If the limestone be an almost pure calcium carbonate it will, on calcination, yield calcium oxide or "quicklime." If, however, the limestone should contain any appreciable percentage of magnesium carbonate, the product will be a mixture of the oxides of calcium and magnesium, commercially known as magnesian lime. A brief sketch of the mineralogic relationships of the various kinds of limestone, in connection with the chemistry of lime burning will be of service at this point of the discussion.

Pure limestone has the composition of the mineral calcite, whose formula is ($CaCO_3$), corresponding to the composition calcium oxide 56 per cent; carbon dioxide, 44 per cent. In the magnesian limestones part of this calcium carbonate is replaced by magnesium carbonate, the resulting rock therefore having a formula of the type ($x\ Ca\ CO_3$), ($y\ Mg\ CO_3$). This replacement may reach the point at which the rock has the composition of the mineral dolomite, an equal mixture of the two carbonates, with the formula ($Ca\ CO_3$),($Mg\ CO_3$),corresponding to the composi-

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Aside from the question of magnesia, a limestone may contain a greater or lesser amount of impurities. Of these the most important are silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3). These impurities, if present in sufficient quantity, will materially affect the properties of the lime produced, as will be noted later under the heads of Hydraulic Limes and Natural Cements.

The carbonate cements may be divided into two classes—

(1) High calcium limes;

(2) Magnesian limes.

High Calcium Limes.—On heating a relatively pure carbonate of lime to a sufficiently high degree, its carbon dioxide is driven off, leaving calcium oxide (CaO) or "quicklime." Under ordinary conditions, the expulsion of the carbon dioxide is not perfectly effected until a temperature of 925° C. is reached. The process is greatly facilitated by blowing air through the kiln, or by the injection of steam. On treating quicklime with water, "slaking" occurs, heat being given off, and the hydrated calcium oxide (CaH_2O_2) being formed. The hydrated oxide will, upon exposure to the atmosphere, slowly reabsorb sufficient carbon dioxide to reassume its original composition as lime carbonate. As this reabsorption can take place only at points where the mortar is exposed to the air, the material in the middle of thick walls never becomes recarbonated. In order to counteract the shrinkage which would otherwise take place during the drying of the mortar, sand is invariably added in the preparation of lime mortars, and as noted above, it is probable that certain reactions take place between the lime and the

case. Such reactions, however, though possibly contributing somewhat to the hardness of old mortars, are only incidental and subsidiary to the principal cause of setting, recarbonation. The presence of impurities in the original limestone affects the character and value of the lime produced. If these impurities, the presence of silica and alumina in sufficient quantities will give hydraulic properties to the resulting limes; such materials will be discussed in the next group as Hydraulic Limes and Natural Cements.

Magnesian Limes.—The presence of any considerable amount of magnesium carbonate in the limestone from which a lime is obtained has a noticeable effect upon the character of the product. If burned at the temperature usual for a pure limestone, magnesian limestones give a lime which slakes slowly without evolving much heat, expands less in slaking, and sets more rapidly than pure lime. To this class belong the well known and much used limes of Canaan (Conn.); Tuckahoe, Pleasantville and Ossining (N. Y.); various localities in New Jersey and Ohio; and Cedar Hollow (Penn.). Magnesian limes are made at a number of points in Iowa, including Dubuque, Lime City, Cedar Valley and other points.* Under certain conditions of burning, pure magnesian limestones yield hydraulic products, but in this case, as in the case of the product obtained by burning pure magnesite, the set seems to be due to the formation of a hydroxide rather than of a carbonate. Magnesian limestones carrying sufficient silica and alumina will give, on burning, a hydraulic cement falling in the next group under the head of Natural Cements.

GROUP II. COMPLEX CEMENTS.

The cementing materials grouped here as Silicate or Hydraulic Cements include all those materials whose setting properties are due to the formation of new compounds, during manufacture or use, and not to the mere reassumption of the original composition of the material from which the cement was made. These new compounds may be formed either by chemical change during manufacture or by chemical interac-

*See Houser, G. L., Iowa Geological Survey, Vol. I, pp. 199-207, 1893. Calvin and Bain, Ibid., Vol. X, pp. 601-604, 1900.

tion, in use, of materials which have merely been mechanically mixed during manufacture.

In the class of silicate cements are included all the materials commonly known as cements by the engineer (natural cements, Portland cement, pozzuolanic cements), together with the hydraulic limes.

Though differing widely in raw material, methods of manufacture and properties, the silicate cements agree in two prominent features; they are all hydraulic (though in very different degrees); and this property of hydraulicity is, in all, due largely or entirely to the formation of tri-calcic silicate ($3\,CaO, SiO_2$). Other silicates of lime, as well as silico-aluminates, may also be formed; but they are relatively unimportant, except in certain of the natural cements and hydraulic limes where the lime-aluminates may be of greater importance than is here indicated. This will be recurred to in discussing the groups named.

The silicate cements are divisible, on technologic grounds, into four distinct classes. The basis for this division is given below. It will be seen that the first named of these classes (the pozzuolanic cements) differs from the other three very markedly, inasmuch as its raw materials are not calcined after mixture; while in the last three classes the raw materials are invariably calcined after mixture. The four classes differ somewhat in composition but more markedly in methods of manufacture and in the properties of the finished cements.

CLASSES OF SILICATE CEMENTS.

1. *Pozzuolanic or Puzzolan Cements;* produced by the mechanical mixture, without calcination, of slaked lime and a silico-aluminous material (the latter being usually a volcanic ash or blast-furnace slag).

2. *Hydraulic Limes;* produced by the calcination, at a temperature not much higher than that of decarbonation, of a siliceous limestone so high in lime carbonate that a considerable amount of free lime appears in the finished product.

3. *Natural Cements;* produced by the calcination, at a temperature between those of decarbonation and clinkering, of a siliceous limestone (which may also carry notable amounts of alumina and of magnesium carbonate) in which the lime ca-

bonate is so low, relatively to the silica and alumina, that little or no free lime appears in the cement.

4. *Portland Cements;* produced by the calcination, at the temperature of semi-vitrefaction ("clinkering") of an artificial mixture of calcareous with silico-aluminous materials, in the proportion of about three parts of lime carbonate to one part of clayey material.

NATURAL CEMENTS.

Natural cements are produced by burning a naturally impure limestone, containing from fifteen to forty per cent of silica, alumina, and iron oxide. This burning takes place at a comparatively low temperature, about that of ordinary lime burning. The operation can therefore be carried on in a kiln closely resembling an ordinary lime kiln. During the burning the carbon dioxide of the limestone is almost entirely driven off, and the lime combines with the silica, alumina and iron oxide, forming a mass containing silicates, aluminates, and ferrites of lime. In case the original limestone contained much magnesium carbonate, the burned rock will also contain a corresponding amount of magnesia.

After burning, the burned mass will not slake if water be added. It is necessary, therefore, to grind it quite finely. After grinding, if the resulting powder (natural cement) be mixed with water it will harden rapidly. This hardening or setting will also take place under water. The natural cements differ from ordinary limes in two noticeable ways:

(1) The burned mass does not slake on the addition of water.

(2) After grinding, the powder has hydraulic properties, i. e., if properly prepared, it will set under water.

Natural cements are quite closely related to both hydraulic limes on the one hand, and Portland cement on the other, agreeing with both in the possession of hydraulic properties. They differ from hydraulic limes, however, in that the burned natural cement rock will not slake when water is poured on it.

The natural cements differ from Portland cements in the following important particulars:

(1) Natural cements are not made by burning carefully prepared and finely ground artificial mixtures, but by burning masses of natural rock.

(2) Natural cements, after burning and grinding, are usually yellow to brown in color and light in weight, their specific gravity being about 2.7 to 2.9; while Portland cement is commonly blue to gray in color and heavier, its specific gravity ranging from 3.0 to 3.2.

(3) Natural cements are always burned at a lower temperature than Portland, and commonly at a *much* lower temperature, the mass of rock in the kiln never being heated high enough to even approach the fusing or clinkering point.

(4) In use, natural cements set more rapidly than Portland cement, but do not attain such a high ultimate strength.

(5) In composition, while Portland cement is a definite product whose percentages of lime, silica, alumina and iron oxide vary only between narrow limits, various brands of natural cements will show very great differences in composition.

The material utilized for natural cement manufacture is invariably a clayey limestone, carrying from 13 to 35 per cent of clayey material, of which 10 to 22 per cent or so is silica, while alumina and iron oxide together may vary from 4 to 16 per cent. It is the presence of these clayey materials which give the resulting cement its hydraulic properties. Stress is often carelessly or ignorantly laid on the fact that many of our best known natural cements carry large percentages of magnesia, but it should, at this date, be realized that magnesia (*in natural cements at least*) may be regarded as being almost exactly interchangeable with lime, so far as the hydraulic properties of the product are concerned. The presence of magnesium carbonate in a natural cement rock is then merely incidental, while the silica, alumina, and iron oxide are essential. The thirty per cent or so of magnesium carbonate which occurs in the cement rock of the Rosendale district, N. S., could be replaced by an equal amount of lime carbonate, and the burnt stone would still give a hydraulic product. If, however, the clayey portion (silica, alumina, and iron oxide) of the Rosendale rock could be removed, leaving only the magnesium and lime carbonates, the

burnt rock would lose all of its hydraulic properties and would yield simply a magnesian lime.

This point has been emphasized because many writers on the subject have either explicitly stated or implied that it is the magnesian carbonate of the Rosendale, Akron, Louisville, Utica and Milwaukee rocks that causes them to yield a natural cement on burning.

PORTLAND CEMENT.

Portland cement is produced by burning a finely ground, artificial mixture containing essentially lime, silica, alumina, and iron oxide, in certain definite proportions. Usually this combination is made by mixing limestone or marl with clay or shale, in which case about three times as much of the lime carbonate should be present in the mixture as of the clay materials. The burning takes place at a high temperature, approaching 3,000° F., and must therefore be carried on in kilns of special design and lining. During the burning, combination of the lime with silica, alumina, and iron oxide takes place. The product of the burning is a semi-fused mass called clinker, and consists of silicates, aluminates and ferrites of lime in certain definite proportions. This clinker must be finely ground. After such grinding the powder (Portland cement) will set under water.

As noted above, under the head of Natural Cements, Portland cement is blue to gray in color, with a specific gravity of 3.0 to 3.2, and sets more slowly than natural cements, but soon attains a higher tensile strength.

PUZZOLAN CEMENTS.

The cementing materials included under this name are made by mixing powdered slaked lime with either a volcanic ash or a blast-furnace slag. The product is therefore simply a mechanical mixture of two ingredients, as the mixture is not burned at any stage of the process. After mixing, the mixture is finely ground. The resulting powder (Puzzolan cement) will set under water.

Puzzolan cements are usually light bluish in color, and of lower specific gravity and less tensile strength than Portland cement. They are better adapted to use under water than to use in air.

PORTLAND CEMENT.

DEFINITION.

In the following section various possible raw materials for Portland cement manufacture will be taken up, and their relative suitability for such use will be discussed. In order that the statements there made may be clearly understood it will be necessary to preface this discussion by a brief explanation regarding the composition and constitution of Portland cement.

Use of term Portland.—While there is a general agreement of opinion as to what is understood by the term Portland cement, a few points of importance are still open questions. The definitions of the term given in specifications are in consequence often vague and unsatisfactory.

It is agreed that the cement mixture must consist essentially of lime, silica and alumina in proportions which can vary but slightly; and that this mixture must be burned at a temperature which will give a semi-fused product—a "clinker." These points must therefore be included in any satisfactory definition. The point regarding which there is a difference of opinion is whether or not cements made by burning a natural rock can be considered true Portlands. The question as to whether the definition of Portland cement should be drawn so as to include or exclude such products is evidently largely a matter of convention; but, unlike most conventional issues, the decision has very important practical consequences. The question at issue may be stated as follows:

If we make artificial mixture of the raw materials and a very high degree of burning the criteria on which to base our definition, we must in consequence of that decision exclude from the class of Portland cements certain well known products manufactured at several points in France and Belgium, by burning a natural rock, without artificial mixture, and at a considerably lower temperature than is attained in ordinary

Portland cement practice. These "natural Portlands" of France and Belgium have always been considered Portland cements by the most critical authorities, though all agree that they are not particularly *high grade* Portlands. So that a definition, based upon the criteria above named, will of necessity exclude from our class of Portland cements some very meritorious products.

There is no doubt that in theory a rock could occur, containing lime, silica and alumina in such correct proportions as to give a good Portland cement on burning. Actually, however, such a perfect cement rock is of extremely rare occurrence. As above stated, certain brands of French and Belgian "Portland" cements are made from such natural rocks, without the addition of any other material; but these brands are not particularly high grade, and in the better Belgian cements the composition is corrected by the addition of other materials to the cement rock, before burning.

The following definition of Portland cement is of importance because of the large amount of cement which will be accepted annually under the specifications* in which it occurs. It is also of interest as being the nearest approach to an official government definition of the material that we have in this country.

"By a Portland cement is meant the product obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceeding 2 per cent of the calcined product."

It will be noted that this definition does not require pulverizing or artificial mixing of the materials prior to burning. It seems probable that the Belgian "natural Portlands" were kept in mind when these requirements were omitted. In dealing with American made cements, however, and the specifications in question are headed, "Specifications for American Portland cement," it is a serious error to omit these requirements. No true Portland cements are at present manufactured in America

*Professional paper No. 28, Corps of Engineers, U. S. A., p. 80.

from natural mixtures, without pulverizing and artificially mixing the materials prior to burning. Several plants, however, have placed on the market so-called Portland cements made by grinding up together the underburned and overburned materials formed during the burning of natural cements. Several of these brands contain from 5 to 15 per cent of magnesia, and under no circumstances can they be considered true Portland cements.

In view of the conditions above noted, the writer believes that the following definition will be found more satisfactory than the one above quoted.

Definition of Portland Cement.—Portland cement is an artificial product obtained by finely pulverizing the clinker produced by burning to semi-fusion an intimate mixture of finely ground calcareous and argillaceous material, this mixture consisting approximately of one part of silica and alumina to three parts of carbonate of lime (or an equivalent amount of lime oxide).

COMPOSITION AND CONSTITUTION.

Portland cements may be said to tend toward a composition approximating to pure tri-calcic silicate ($3\,CaO, SiO_2$) which would correspond to the proportion CaO 73.6 per cent, SiO_2 26.4 per cent. As can be seen, however, from the analyses quoted later, actual Portland cements as at present made differ in composition somewhat markedly from this. Alumina is always present in considerable quantity, forming with part of the lime, the dicalcic aluminate ($2\,CaO, Al_2O_3$). This would give, as stated by Newberry, for the general formula of a pure Portland—

$$x\,(3\,CaO, SiO_2) + y\,(2\,CaO, Al_2O_3).$$

But the composition is still further complicated by the presence of accidental impurities, or intentionally added ingredients. These last may be simply adulterants, or they may be added to serve some useful purpose. Calcium sulphate is a type of the latter class. It serves to retard the set of the cement, and, in small quantities, appears to have no injurious effect which would prohibit its use for this purpose. In dome kilns, sufficient sulphur trioxide is generally taken up by the

cement from the fuel gases to obviate the necessity for the later addition of calcium sulphate, but in the rotary kiln its addition to the ground cement, in the form of either powdered gypsum or plaster of Paris, is a necessity.

Iron oxide, within reasonable limits, seems to act as a substitute for alumina, and the two may be calculated together. Magnesium carbonate is rarely entirely absent from limestones or clays, and magnesia is therefore almost invariably present in the finished cement. Though magnesia, when magnesium carbonate is burned at low temperature, is an active hydraulic material, it does not combine with silica or alumina at the clinkering heat employed in Portland cement manufacture. At the best it is an inert and valueless constituent in the cement; many regard it as positively detrimental in even small amounts, and because of this feeling manufacturers prefer to carry it as low as possible. Newberry has stated that in amounts of less than three and one-half per cent it is harmless, and American Portlands from the Lehigh district usually reach well up toward that limit. In European practice it is carried somewhat lower.

Raw Materials.

GENERAL CONSIDERATIONS.

For the purposes of the present chapter it will be sufficiently accurate to consider that a Portland cement mixture, when ready for burning, will consist of about seventy-five per cent of lime carbonate ($Ca\,CO_3$) and twenty per cent of silica (SiO_2), alumina ($Al_2\,O_3$) and iron oxide ($Fe_2\,O_3$) together, the remaining five per cent including any magnesium carbonate, sulphur and alkalies that may be present.

The essential elements which enter into this mixture—lime, silica, alumina and iron—are all abundantly and widely distributed in nature, occurring in different forms in many kinds of rocks. It can therefore be readily seen that, theoretically, a satisfactory Portland cement mixture could be prepared by combining, in an almost infinite number of ways and proportions, many possible raw materials. Obviously, too, we might expect to find perfect gradations in the artificialness of the

mixture, varying from one extreme where a natural rock of absolutely correct composition was used to the other extreme where two or more materials, in nearly equal amounts, are required to make a mixture of correct composition.

The almost infinite number of raw materials which are theoretically available are, however, reduced to a very few in practice under existing commercial conditions. The necessity for making the mixture as cheaply as possible rules out of consideration a large number of materials which would be considered available if chemical composition was the only thing to be taken into account. Some materials otherwise suitable are too scarce; some are too difficult to pulverize. In consequence, a comparatively few combinations of raw materials are actually used in practice.

In certain localities deposits of argillaceous (clayèy) limestone or "cement rock" occurs, in which the lime, silica, alumina and iron oxide exist in so nearly the proper proportions that only a relatively small amount (about ten per cent or so) of other material is required in order to make a mixture of correct composition.

In the majority of plants, however, most or all of the necessary lime is furnished by one raw material, while the silica, alumina and iron oxide are largely or entirely derived from another raw material. The raw material which furnished the lime is usually natural, a limestone, chalk or marl, but occasionally an artificial product is used, such as the chemically precipitated lime carbonate which results as waste from alkali manufacture. The silica, alumina and iron oxide of the mixture are usually derived from clays, shales or slates; but in a few plants blast-furnace slag is used as the silica-aluminous ingredient in the manufacture of true Portland cement.

The various combinations of raw materials which are at present used in the United States in the manufacture of Portland cement may be grouped under six heads. This grouping is as follows:

1. Argillaceous limestone (cement rock) and pure limestone.
2. Pure hard limestone and clay or shale.
3. Soft chalky limestone and clay.

4. Marl and clay.
5. Alkali waste and clay.
6. Slag and limestone.

ORIGIN AND GENERAL CHARACTERS OF LIMESTONES.

The cement materials which are described in the four following sections as argillaceous limestone or cement rock, pure hard limestone, chalk, and marl, though differing sufficiently in their physical and economic characters to be discussed separately and under different names, agree in that they are all forms of limestone. The origin, chemical composition, physical characters, and properties of limestone will therefore be briefly taken up in the present chapter to serve as an introduction to the more detailed statements concerning the various types of limestone to be found in the succeeding chapters.

ORIGIN OF LIMESTONES.*

Limestones have been formed largely by the accumulation at the sea bottom of the calcareous remains of such organisms as the foraminifera, corals, and mollusks. Most of the thick and extensive limestone deposits of the United States were probably deep-sea deposits formed in this way. Many of these limestones still show the fossils of which they were formed, but in others all trace of organic origin has been destroyed by the fine grinding to which the shells and corals were subjected before their deposition on the sea bottom. It is probable, also, that part of the calcium carbonate of these limestones was a purely chemical deposit from solution, cementing the shell fragments together.

A far less extensive class of limestones—though important in the present connection—owe their origin to the indirect action of organisms. The "marls," so important today as Portland cement materials, fall in this class. As the class is of limited extent, however, its methods of origin may be dismissed here, but will be described later.

Deposition from solution by purely chemical means has undoubtedly given rise to numerous limestone deposits. When

*For a more detailed discussion of this subject the reader will do well to consult Chapter 8 of Prof. J. F. Kemp's "Handbook of Rocks."

this deposition took place in caverns or in the open air, it gave rise to onyx deposits and to the "travertine marls" of certain Ohio and other localities; when it took place in isolated portions of the sea through the evaporation of the sea water it gave rise to the limestone beds which so frequently accompany deposits of salt and gypsum.

VARIETIES OF LIMESTONE.

A number of terms are in general use for the different varieties of limestone, based upon differences of origin, texture, composition, etc. The more important of these terms will be briefly defined.

The *marbles* are limestone which, through the action of heat and pressure, have become more or less distinctly crystalline. The term *marl*, as at present used in cement manufacture, is applied to a loosely cemented mass of lime carbonate formed in lake basins. *Calcareous tufa* and *travertine* are more or less compact limestones deposited by spring or stream waters along their courses. *Oolitic limestones*, so called because of their resemblance to a mass of fish-roe, are made up of small, rounded grains of lime carbonate. *Chalk* is a fine-grained limestone composed of finely comminuted shells, particularly those of the foraminifera. The presence of much silica gives rise to a *siliceous* or *cherty* limestone. If the silica present is in combination with alumina, the resulting limestone will be *clayey* or *argillaceous*.

CHEMICAL COMPOSITION OF LIMESTONE.

A theoretically pure limestone is merely a massive form of the mineral calcite. Such an ideal limestone would therefore consist entirely of calcium carbonate or carbonate of lime, with the formula $CaCO_3$ (CaO, CO_2), corresponding to the composition calcium oxide (CaO) 56 per cent, carbon dioxide or carbonic acid (CO_2) 44 per cent.

As might be expected, the limestones we have to deal with in practice depart more or less widely from this theoretical composition. These departures from ideal purity may take place along either of two lines:

a. The presence of magnesia in place of part of the lime.

b. The presence of silica, iron, alumina, alkalies, or other impurities.

It seems advisable to discriminate between these two cases. even though a given sample of limestone may fall under both heads, and they will, therefore, be discussed separately.

The presence of magnesia in place of part of the lime.—The theoretically pure limestones are, as above noted, composed entirely of calcium carbonate and correspond to the chemical formula $CaCO_3$. Setting aside for the moment the question of the presence or absence of such impurities as iron, alumina, silica, etc., it may be said that lime is rarely the only base in a limestone. During or after the formation of the limestone a certain percentage of magnesia is usually introduced in place of a part of the lime, thus giving a more or less magnesian limestone. In the magnesian limestones part of this calcium carbonate is replaced by magnesium carbonate ($Mg\,CO_3$), the general formula for a magnesian limestone being therefore

$$x\,Ca\,CO_3 + y\,Mg\,CO_3$$

In this formula x may vary from 100 per cent to zero, while y will vary inversely from zero to 100 per cent. In the particular case of this replacement where the two carbonates are united in equal *molecular* proportions, the resultant rock is called dolomite. It has the formula ($CaCO_3$, $MgCO_3$) corresponding to the composition calcium carbonate 54.35 per cent, magnesium carbonate 45.65 per cent. In the case where the calcium carbonate has been entirely replaced by magnesium carbonate, the resulting pure carbonate of magnesia is called magnesite, having the formula $MgCO_3$ and the composition magnesia (MgO) 47.6 per cent, carbon dioxide (CO_2) 52.4 per cent.

Rocks of this series may therefore vary in composition from pure calcite limestone at one end of the series to pure magnesite at the other. The term limestone has, however, been restricted in general use to that part of the series lying in composition between calcite and dolomite, while all those more uncommon phases carrying more magnesium carbonate than the 45.65 per cent are usually described simply as impure magnesites.

The presence of much magnesia in the finished cement is considered undesirable, 3½ per cent being the maximum permissible under most specifications, and therefore the limestone to be used in Portland cement manufacture should carry not over five to six per cent of magnesium carbonate.

Though magnesia is often described as an "impurity" in limestone, this word, as can be seen from the preceding statements, hardly expresses the facts in the case. The magnesium carbonate present, whatever its amount, simply serves to replace an equivalent amount of calcium carbonate, and the resulting rock, whether little or much magnesia is present, is still a pure carbonate rock. With the impurities to be discussed in later paragraphs, however, this is not the case. Silica, alumina, iron, sulphur, alkalies, etc., when present, are actual impurities, not merely chemical replacements of part of the calcium carbonate.

The presence of silica, iron, alumina, alkalies and other impurities.—Whether a limestone consists of pure calcium carbonate or more or less of magnesium carbonate, it may also contain a greater or less amount of distinct impurities. From the point of view of the cement manufacturer, the more important of these impurities are silica, alumina, iron, alkalies and sulphur, all of which have a marked effect on the value of the limestone as a cement material. These impurities will, therefore, be taken up in the order in which they are named above.

The silica in a limestone may occur either in combination with alumina, as a clayey impurity, or not combined with alumina. As the effect on the value of the limestone would be very different in the two cases they will be take up separately.

Silica alone.—Silica, when present in a limestone containing no alumina may occur in one of three forms, and the form in which it occurs is of great importance in connection with cement manufacture.

(1) In perhaps its commonest form, silica is present in nodules, masses or beds of flint or chert. Silica occurring in this form will not readily enter into combination with the lime of a cement mixture, and a cherty or flinty limestone is, therefore, almost useless in cement manufacture.

(2) In a few cases, as in the hydraulic limestone of *Teil*. France, a large amount of silica is present and very little alumina, notwithstanding which the silica readily combines with the lime on burning. It is probable that in such cases the silica is present in the limestone in a very finely divided condition, or possibly as hydrated silica, possibly as the result of chemical precipitation or of organic action. In the majority of cases, however, a highly siliceous limestone will not make a cement on burning unless it contains alumina in addition to the silica.

(3) In the crystalline limestone (marbles) and less commonly in uncrystalline limestones, whatever silica is present may occur as a complex silicate in the form of shreds of mica, hornblende, or other silicate mineral. In this form silica is somewhat intractable in the kiln, and mica and other silicate minerals are therefore to be regarded as inert and useless impurities in a cement rock. These silicates will flux at a lower temperature than pure silica and are thus not so troublesome as flint or chert. They are, however, much less serviceable than if the same amount of silica were present in combination with alumina as a clay.

Silica with Alumina.—Silica and alumina, combined in the form of clay, are common impurities in limestone, and are of special interest to the cement manufacturer. The best known example of such an argillaceous limestone is the cement rock of the Lehigh district of Pennsylvania. Silica and alumina, when present in this combined form, combine readily with the lime under the action of heat, and an argillaceous limestone therefore forms an excellent basis for a Portland cement mixture.

Iron.—Iron when present in a limestone occurs commonly as the oxide (Fe_2O_3) or sulphide (FeS_2); more rarely as iron carbonate or in a complex silicate. Iron in the oxide, carbonate or silicate forms is a useful flux, aiding in the combination of the lime and silica in the kiln. When present as a sulphide, in the form of the mineral pyrite, it is to be avoided in quantities above two or three per cent.

PHYSICAL CHARACTERS OF LIMESTONES.

In texture, hardness and compactness, the limestones vary from the loosely consolidated marls through the chalks to the hard, compact limestones and marbles. Parallel with these variations are variations in absorptive properties and density. The chalky limestones may run as low in specific gravity as 1.85, corresponding to a weight of about 110 pounds per cubic foot, while the compact limestones commonly used for building purposes range in specific gravity between 2.3 and 2.9, corresponding approximately to a range in weight of from 140 to 185 pounds per cubic foot.

From the point of view of the Portland cement manufacturer, these variations in physical properties are of economic interest chiefly in their bearing upon two points: the percentage of water carried by the limestone as quarried, and the ease with which the rock may be crushed and pulverized. To some extent the two properties counterbalance each other, the softer the limestone the more absorbent it is likely to be. These purely economic features will be discussed in more detail later.

EFFECT OF HEATING ON LIMESTONE.

On heating a non-magnesian limestone to or above 300° C., its carbon dioxide will be driven off, leaving quicklime (calcium oxide, CaO). If a magnesian limestone be similarly treated, the product would be a mixture of calcium oxide and magnesium oxide (MgO). The rapidity and perfection of this decomposition can be increased by passing steam or air through the burning mass. In practice this is accomplished either by the direct injection of air or steam, or more simply by thoroughly wetting the limestone before putting it into the kiln.

If, however, the limestone contains an appreciable amount of silica, alumina and iron, the effects of heat will not be of so simple a character. At temperatures of 800° C. and above these clay impurities will combine with the lime oxide, giving silicates, aluminates and related salts of lime. In this manner a natural cement will be produced. An artificial mixture of certain and uniform composition, burned at a higher tempera-

ture, will give a Portland cement, the details of whose manufacture are discussed on later pages.

Raw Materials Actually in Use.

ARGILLACEOUS LIMESTONE: CEMENT ROCK.

An argillaceous limestone containing approximately 75 per cent of lime carbonate and 20 per cent of clayey materials (silica, alumina and iron oxide) would, of course, be the ideal material for use in the manufacture of Portland cement, as such a rock would contain within itself in the proper proportions all the ingredients necessary for the manufacture of a good Portland. It would require the addition of no other material, but when burnt alone would give a good cement. This ideal cement material is, of course, never realized in practice, but certain deposits of argillaceous limestone approach the ideal composition very closely.

The most important of these argillaceous limestone or "cement rock" deposits is, at present, that which is so extensively utilized in Portland cement manufacture in the "Lehigh district" of Pennsylvania and New Jersey. As this area still furnishes about two-thirds of all the Portland cement manufactured in the United States, its raw materials will be described in some detail.

CEMENT ROCK OF THE LEHIGH DISTRICT.

The Lehigh district of the cement trade comprises parts of Berks, Lehigh, and Northampton counties, Pennsylvania, and of Warren county, New Jersey. Within this relatively small area about twenty Portland cement mills are located, producing slightly over two-thirds of the entire American output. As deposits of the cement rock used by these plants extend far beyond the present "Lehigh district," a marked extension of the district will probably take place as the need for larger supplies of raw material becomes more apparent.

The "cement rock" of the Lehigh district is a highly argillaceous limestone of Trenton (Lower Silurian) age. The formation is about 300 feet in thickness in this area. The rock

is very dark gray in color and usually has a slaty fracture. In composition it ranges from about 60 per cent lime carbonate with 30 per cent clayey material, up to about 80 per cent lime carbonate with 15 per cent of silica, alumina and iron. The lower beds of the formation are always higher in lime carbonate than are the beds nearer the top of the formation. The content of magnesium carbonate in these cement rocks is always high (as Portland cement materials go), ranging from 3 to 6 per cent.

Near, and in some cases immediately underlying these cement beds, are beds of purer limestone ranging from 85 to 96 per cent lime carbonate. The usual practice in the Pennsylvania and New Jersey plants has been, therefore, to mix a relatively small amount of this purer limestone with the low lime "cement rock" in such proportions as to give a cement mixture of proper composition.

The economic and technologic advantages of using such a combination of materials are very evident. Both the pure limestone and the cement rock, particularly the latter, can be quarried very easily and cheaply. As quarried, they carry but little water so that the expense of drying them is slight. The fact that about four-fifths of the cement mixture will be made up of a natural cement rock permits coarser grinding of the raw mixture than would be permissible in plants using pure limestone or marl with clay. This point is more fully explained on a later page. It seems probable, also, that when using a natural cement rock as part of the mixture the amount of fuel necessary to clinker the mixture is less than when pure limestone is mixed with clay.

Such mixtures of argillaceous limestone or "cement rock" with a small amount of pure limestone evidently possess important advantages over mixtures of pure hard limestone or marl with clay. They are, on the other hand, less advantageous as cement materials than the chalky limestones.

The analyses in table 2 are fairly representative of the materials employed in the Lehigh district. The first four analyses are of "cement rock;" the last two are of the purer limestone used for mixing with it.

TABLE [illegible] ANALYSES OF LEHIGH DISTRICT CEMENT MATERIALS.

		Cement Rock.				Limestone	
[illegible]	10.02	9.52	14.52	16.10	3.02	[illegible]	
[illegible]	6.[illegible]	4.[illegible]	6.52	2.20	1.90	[illegible]	
[illegible]	.....	.....	.....	.....	.....	[illegible]	
[illegible]	[illegible]	[illegible]	73.52	76.23	92.05	[illegible]	
[illegible]	4.[illegible]	4.[illegible]	4.69	3.54	3.04	[illegible]	

[illegible] IN OTHER PARTS OF THE UNITED STATES.

was not due to any defects in the limestone used, a certain prejudice arose against the use of the hard limestones. In recent years, however, this has disappeared, and a very large proportion of the American output is now made from mixtures of limestone with clay or shale. This reestablishment in favor of the hard limestone is doubtless due, in great part, to recent improvements in grinding machinery, for the purer limestones are usually much harder than argillaceous limestones like the Lehigh district "cement rock," and it was very difficult to pulverize them finely and cheaply with the crushing appliances in use when the Portland cement industry was first started in America.

A series of analyses of representative pure hard limestones, together with analyses of the clays or shales with which they are mixed, is given below.

ANAYLSES OF PURE HARD LIMESONES AND CLAYEY MATERIALS.

	Limestones			
Silica (SiO_2)	1.72	0.86	0.56	0.40
Alumina (Al_2O_3)	1.63	0.63	1.23	0.44 (alumina and iron oxide together)
Iron oxide (Fe_2O_3)	6.59	1.03	0.29	
Lime carbonate ($CaCO_3$)	90.58	97.06	97.23	97.99
Magnesium carbonate ($MgCO_3$)			0.75	0.42
	Clays and Shales.			
Silica (SiO_2)	63.56	55.80	56.30	60.00
Alumina (Al_2O_3)	27.32 (alumina and iron oxide together)	30.20 (alumina and iron oxide together)	29.86 (alumina and iron oxide together)	23.26
Iron oxide (Fe_2O_3)				4.32
Lime carbonate ($CaCO_3$)	3.60	2.54		1.70
Magnesium carbonate ($MgCO_3$)	2.60			1.50

The first limestone analysis given in the above table represents a curious type, used in several plants in the Middle West. As will be noted, it is a relatively impure limestone, but its principal impurity is iron oxide.

It contains 8.22 per cent of iron oxide and alumina, as compared with 1.72 per cent of silica; and therefore demands great care in the selection of a suitable high-silica clay to mix with it.

SOFT LIMESTONE: CHALK.

ORIGIN AND GENERAL CHARACTER.

Chalk, properly speaking, is a pure carbonate of lime, composed of the remains of the shells of minute organisms, among which those of foraminifera are especially prominent. The chalks and soft limestones discussed here agree, not only in having usually originated in this way, but also in being rather soft and therefore readily and cheaply crushed and pulverized. As Portland cement materials they are, therefore, almost ideal. One defect, however, which to a small extent counterbalances their obvious advantages is the fact that most of these soft, chalky limestones absorb water quite readily. A chalky limestone which in a dry season will not carry over two per cent of moisture as quarried, may in consequence of prolonged wet weather show as high as fifteen or twenty per cent of water. This difficulty can of course be avoided if care be taken in quarrying to avoid unnecessary exposure to water and, if necessary, to provide facilities for storing a supply of the raw materials during wet seasons.

GEOGRAPHIC AND GEOLOGIC DISTRIBUTION IN THE UNITED STATES.

The chalks and chalky limestones are confined almost entirely to certain southern and western states. They are all of approximately the same geologic ages, Cretaceous or Tertiary, and are mostly confined to one division of the Cretaceous. The principal chalk or soft limestone deposits available for use in Portland cement manufacture occur in three widely separated areas, occupying respectively, (a) parts of Alabama and Mississippi, (b) parts of Texas and Arkansas, (c) parts of Iowa, Nebraska, North and South Dakota.

COMPOSITION.

In composition these chalks, or "rotten limestones," vary from a rather pure calcium carbonate, low in both magnesia and clayey materials to an impure clayey limestone, requiring little additional clay to make it fit for use in Portland cement manufacture. Analyses quoted from various authors of a

number of these chalky limestones are given in table C, and will serve to show their range of composition.

TABLE C. CHALKY LIMESTONES.

	Demopolis, Ala.	San Antonio, Tex.	Dallas, Tex.	White Cliffs, Ark.	Yankton, S. Dak.	Milton, N. Dak.
Silica	12.13	5.77	23.55	7.97	8.20	9.15
Alumina	4.17	2.14	1.50	1.09	7.07	4.80
Iron oxide	3.28					2.30
Lime carbonate	75.07	90.15	70.21	88 64	83.59	63.75
Magnesian carbonate	.92	.58	.58	.73	n. d.	1.25

FRESH WATER MARLS.

Marls, in the sense in which the term is used in the Portland cement industry, are incoherent limestones which have been deposited in the basins of existing or extinct lakes. So far as chemical composition is concerned, marls are practically pure limestones, being composed almost entirely of calcium carbonate. Physically, however, they differ greatly from the compact rocks which are commonly described as limestones, for the marls are granular, incoherent deposits. This curious physical character of marls is due to the conditions under which they have been deposited, and varies somewhat according to the particular conditions which governed their deposition in different localities.

A warning to the reader concerning other uses of the term "marl," may profitably be introduced here. The meaning above given is that in which the term marl is commonly used in the cement industry at the present day but in geological and agricultural reports, particularly in those issued before the Portland cement industry became prominent in this country, the term marl has been used to cover several very different substances. The following three uses of the term will be found particularly common, and must be guarded against when such reports are being examined in search for descriptions of deposits of cement materials.

(1) In early days the terms "marls" and "marlytes" were used to describe deposits of calcareous shales, and often covered

shales which were not particularly calcareous. This use of the term will be found in many of the earlier geological reports issued by New York, Ohio, and other interior states.

(2) In New Jersey and the states southward bordering on the Atlantic and the Gulf of Mexico, the term marl is commonly applied to deposits of soft, chalky or unconsolidated limestone, often containing considerable clayey and phosphatic matter. These limestones are of marine origin, and are not related to the fresh water marl deposits which are the subject of the present chapter.

(3) In the same states as are included in the last paragraph, but particularly in New Jersey and Virginia, large deposits of the so-called "greensand marls" occur. This material is in no way related to the true marls (which are essentially lime carbonates), but consists almost entirely of an iron silicate, with very small percentages of clayey, calcareous and phosphatic matter.

ORIGIN OF MARLS.

The exact cause of the deposition of marls has been the subject of much investigation and discussion, particularly in the past few years, since they have become of economic importance. The reader who wishes to obtain further details concerning this question will do well to refer to the following series of papers.

(1) Blatchley, W. S., and Ashley, G. H. The lakes of northern Indiana and their associated marl deposits, in 25th Ann. Rept. Indiana Dept. Geology and Natural Resources, pp. 31-321.

(2) Davis, C. A. A contribution to the natural history of marl. Journal of Geology, Vol. 8, pp. 485-497.

(3) Davis, C. A. Second contribution to the natural history of marl. Journal of Geology, Vol. 9, pp. 491-506.

(4) Davis, C. A. A contribution to the natural history of marl. Vol. 8, pt. 3. Reports Michigan Geological Survey, pp. 65-102.

(5) Lane, A. C. Notes on the origin of Michigan bog limes, Vol. 8, pt. 3, Reports Michigan Geological Survey, pp. 199-223.

Disregarding the points in controversy, which are of no particular practical importance, it may be said that marls are deposited in lakes by spring or stream waters carrying lime car-

bonate in solution. The actual deposition is in part due to purely physical and chemical causes, and in part to the direct or indirect action of animal or vegetable life. The result, in any case, is that a calcareous deposit forms along the sides and over the bottom of the lake, this deposit consisting of lime carbonate, mostly in a finely granular form, interspersed with shells and shell fragments.

GEOGRAPHIC DISTRIBUTION OF MARL DEPOSITS.

The geographic distribution of marl deposits is intimately related to the geologic history of the region in which they occur. Marl beds are, as indicated in the preceding section, the result of the filling of lake basins. Lakes are not common except in those portions of the United States which were affected by glacial action, since lakes are in general due to the damming of streams by glacial material. Workable marl deposits, therefore, are almost exclusively confined to those portions of the United States and Canada lying north of the former southern limit of the glaciers.

Marl beds are found in the New England states where they are occasionally of important size, and in New York, where large beds occur in the central and western portions of the state. Deposits are frequent and important in Michigan and in the northern portions of Ohio, Indiana and Illinois. Marl beds occur in Wisconsin and Minnesota, but have not been as yet exploited for cement manufacture.

COMPOSITION.

As shown by the analyses below, marls are usually very pure lime carbonates. They therefore require the addition of considerable clay to bring them up to the proper composition for a Portland cement mixture.

The marls are readily excavated, but necessarily carry a large percentage of water. The mixture, on this account, is commonly made in the wet way, which necessitates driving off a high percentage of water in the kilns. Analyses of typical marls and clays are given in the following tables:

ANALYSES OF MARLS AND CLAYS USED IN CEMENT PLANTS.

	Marl.			Clay.		
Silica	0.25	3.0	1 60	40.48	52.0	63.75
Alumina	.10	....	1.55	20.95	17.0	16.40
Iron oxide					5.0	6.35
Lime carbonate	94.39	93.0	88.9	25.80	20.0	4.0
Magnesium carbonate	.38	1.5	.94	99	.....	2 1

ALKALI WASTE.

A very large amount of waste material results from the process used at alkali works in the manufacture of caustic soda. This waste material is largely a precipitated form of calcium carbonate, and if it is sufficiently free from impurities, it furnishes a cheap source of lime for use in Portland cement manufacture.

The availability of alkali waste for this purpose depends largely on what process was used at the alkali plant. Leblanc process waste, for example, carries a very large percentage of sulphides, which prevents its use as a Portland cement materlal. Waste resulting from the use of the ammonia process on the other hand, is usually a very pure mass of lime, mostly in the form of carbonate, though a little lime hydrate is commonly present. As pyrite is not used in the ammonia process, its waste is usually low enough in sulphur to be used as a cement material. The waste may carry a low or a very high percentage of magnesia, according to the character of the limestone that has been used in the alkali plant. When a limestone low in magnesium carbonate has been used, the resulting waste is a very satisfactory Portland cement material.

The following analyses are fairly representative of the waste obtained at alkali plants using the ammonia process:

ANALYSES OF ALKALI WASTE.

	1	2	3	4
Silica (SiO_2)	0.60	1.75	1.98	0.98
Alumina (Al_2O_3)	3.04	0.61	1.41	1 62
Iron oxide (Fe_2O_3)			1.38	
Lime (CaO)	53.33	50.60	48.29	50.40
Magnesia (MgO)	0.48	5.35	1.51	4.97
Alkalies (Na_2O, K_2O)	0.20	0.64	0.64	0.50
Sulphur trioxide (SO_3)	n. d.	n. d.	1.26	n. d.
Sulphur (S)	n. d.	0.10	n. d.	0.06
Carbon dioxide (CO_2)	42.43	41.70	39.60	n. d.
Water and organic matter	n. d.		3 80	n. d.

Of the analyses quoted in the preceding table, those in the first and third columns represent materials which are actually used in Portland cement manufacture in England and the United States. The alkali wastes whose analyses are given in the second and fourth columns are notably too high in magnesia to be advisable for such use.

BLAST FURNACE SLAG.

True Portland cements, which must be sharply distinguished from the slag (or puzzolan) cements described on later pages of this report can be made from mixtures which contain blast furnace slag as one ingredient. In this case the slag is intimately mixed with limestone and the mixture is finely powdered. It is then burned in kilns and the resulting clinker pulverized.

The slags from iron furnaces consist essentially of lime (CaO), silica (SiO_2) and alumina (Al_2O_3), though small percentages of iron oxide (FeO), magnesia (MgO) and sulphur (S), are commonly present. Slag may, therefore, be regarded as a very impure limestone or a very calcareous clay, from which the carbon dioxide has been driven off. Two plants are at present engaged in the manufacture of true Portland cement from slag, in the United States.

The slag used at a German Portland cement plant has the following range in composition.

COMPOSITION OF SLAG USED IN PORTLAND CEMENT MANUFACTURE.

Silica (SiO_2)	30.	35.
Alumina (Al_2O_3)	10.	14.
Iron oxide (FeO)	0.2	1.2
Lime (CaO)	46.	49.
Magnesia (MgO)	0.5	3.5
Sulphur trioxide (SO_3)	0.2	0.6

CLAYS AND SHALES.

Clays are ultimately derived from the decay of older rocks, the finer particles resulting from this decay being carried off and deposited by streams along their channels, in lakes, or along parts of the sea coast or sea bottom as beds of clay. In chemical composition the clays are composed essentially of

silica and alumina, though iron oxide is almost invariably present in more or less amount, while lime, magnesia, alkalies and sulphur are of frequent occurrence, though usually in small percentages.

Shales are clays which have become hardened by pressure. The so-called "fire clays" of the coal measures are usually shales, as are many of the other "clays" of commerce.

For use as Portland cement materials clays or shales should be as free as possible from gravel and sand, as the silica present as pebbles or grit is practically inert in the kiln unless ground more finely than is economically practicable. In composition they should not carry less than 55 per cent of silica, and preferably from 60 to 70 per cent. The alumina and iron oxide together should not amount to more than one-half the percentage of silica, and the composition will usually be better the nearer the ratio $Al_2O_3 + Fe_2O_3 = \frac{SiO_2}{3}$ is approached.

Nodules of lime carbonate, gypsum or pyrite, if present in any quantity, are undesirable; though the lime carbonate is not absolutely injurious. Magnesia and alkalies should be low, preferably not above three per cent.

SLATE.

Slate is, so far as origin is concerned, merely a form of shale in which a fine, even and parallel cleavage has been developed by pressure. In composition, therefore, it will vary exactly as do the shales, and so far as composition alone is concerned, slate would not be worthy of more attention, as a Portland cement material, than any other shale.

Commercial considerations in connection with the slate industry, however, make slate a very important possible source of cement material. Good roofing slate is a relatively scarce material, and commands a good price when found. In the preparation of roofing slate for the market so much material is lost during sawing, splitting, etc., that only about ten to twenty-five per cent of the amount quarried is salable as slate. The remaining seventy-five to ninety per cent is of no service to the slate miner. It is sent to the dump heap and is a continual source of trouble and expense. This very material,

however, as can be seen from the analyses quoted below, is often admirable for use, in connection with limestone, in a Portland cement mixture. As it is a waste product, it could be obtained very cheaply by the cement manufacturer.

COMPOSITION OF AMERICAN ROOFING SLATES.

	Maximum	Average.	Minimum.
Silica (SiO_2)	68.62	60.64	54.05
Alumina (Al_2O_3)	24.71	18.05	9.77
Iron oxides (FeO, Fe_2O_3)	10.66	6.87	2.18
Lime (CaO)	5.23	1.54	....
Magnesia (MgO)	6.43	2.60	0.12
Alkalies (K_2O, Na_2O)	8.63	4.74	1.93
Ferrous sulphide (FeS_2)	....	0.38	....
Carbon dioxide (CO_2)	....	1.47	....
Water of combination	....	3.51	....
Moisture, below 110°C	....	0.62	....

Factors Determining the Value of Deposits of Cement Materials.

It seems desirable to give a somewhat detailed discussion of the factors which influence the value of limestone, marl or chalk or clay for Portland cement manufacture. Determining the possible value, for Portland cement manufacture, of a deposit of raw material is a complex problem, since the value depends upon a number of distinct factors, all of which must be given due consideration. The more important of these factors are:

(1) Chemical composition of the material.

(2) Physical character of the material.

(3) Amount of material available.

(4) Location of the deposit with respect to transportation routes.

(5) Location of the deposit with respect to fuel supplies.

(6) Location of the deposit with respect to markets.

METHODS AND COST OF EXCAVATION OF RAW MATERIALS.

The natural raw materials used at present in Portland cement manufacture are obtained by one of three methods,—(a) quarrying, (b) mining, and (c) dredging. When the cement

manufacturer is given an opportunity to choose between these different methods of excavation, his choice will depend partly on the physical character of the material to be excavated and partly on the topographic and geologic conditions. Usually, however, there is no opportunity for a choice of methods, for in any given case one of the methods will be so evidently the only possible mode of handling the material as to leave no room for other considerations.

The three different methods of excavation will first be briefly considered, after which the cost of raw materials at the mill will be discussed.

Quarrying.—In the following pages the term "quarrying" will be used to cover all methods of obtaining raw materials from open excavations—quarries, cuts or pits—whether the material excavated be a limestone, a shale or a clay. Quarrying is the most natural and common method of excavating the raw materials for cement manufacture. If marl, which is usually worked by dredging, be excluded from consideration, it is probably within safe limits to say that 95 per cent of the raw materials used at American Portland cement plants are obtained by quarrying. If marls be included, the percentages excavated by the different methods would probably be about as follows: Quarrying, 88 per cent; dredging, 10 per cent; mining, 2 per cent.

In the majority of limestone quarries the material is blasted out and loaded by hand on to cars or carts. In a few limestone quarries a steam shovel is employed to do the loading, and in shale quarries this use of steam shovels is more frequent. In certain clay and shale pits, where the materials are of suitable character, the steam shovel does all the work, both excavating and loading the raw materials.

The rock is usually shipped to the mill as quarried without any treatment except sledging it to a convenient size for loading. At a few quarries, however, a crushing plant is installed at the quarry, and the rock is sent as crushed stone to the mill. A few plants also have installed their driers at the quarry, and dry the stone before shipping it to the mill. Except the saving of mill space thus attained, this practice seems to have little to commend it.

Mining.—The term "mining" will be used, in distinction from "quarrying," to cover methods of obtaining any kind of raw material by underground workings, through shafts or tunnels. Mining is, of course, rarely employed in excavating materials of such low value per ton as the raw materials for Portland cement manufacture. Occasionally, however, when a thin bed of limestone or shale is being worked, its dip will carry it under such a thickness of other strata as to make mining cheaper than stripping and quarrying, for that particular case.

Mining is considerably more expensive work than quarrying but there are a few advantages about it that serve to counterbalance the greater cost per ton of raw material. A mine can be worked steadily and economically in all kinds of weather, while an open cut or quarry is commonly in a more or less unworkable condition for about three months of the year. Material won by mining is, moreover, always dry and clean.

Dredging.—The term "dredging" will be here used to cover all methods of excavating soft, wet, raw materials. The fact that the materials are wet implies that the deposit occurs in a basin or depression; and this in turn implies that the mill is probably located at a higher elevation than the deposit of raw material, thus necessitating up-hill transportation to the mill.

The only raw material for Portland cement manufacture that is extensively worked by dredging, in the United States, is marl. Occasionally the clay used is obtained from deposits overlain by more or less water; but this is rarely done except where the marl and clay are interbedded or associated in the same deposit.

A marl deposit, in addition to containing much water diffused throughout its mass, is usually covered by a more or less considerable depth of water. This will frequently require the partial draining of the basin in order to get tracks laid near enough to be of service.

In dredging marl the excavator is frequently mounted on a barge, which floats in a channel resulting from previous excavation. Occasionally, in deposits which either were originally covered by very little water or have been drained, the shovel is

mounted on a car, running on tracks laid along the edge of the deposit.

The material brought up by the dredge may be transported to the mill in two different ways, the choice depending largely upon the manufacturing processes in use at the plant. At plants using dome or chamber kilns, or where the marl is to be dried before sending to the kiln, the excavated marl is usually loaded by the shovel on cars, and hauled to the mill by horse or steam power. At normal marl plants, using a very wet mixture, it is probable that the second method of transportation is more economical. This consists of dumping the marl from the excavator into tanks, adding sufficient water to make it flow readily, and pumping the fluid mixture to the mill in pipes.

COST OF RAW MATERIALS AT MILL.

The most natural way, perhaps, to express the cost of the raw materials delivered at the mill would be to state it as being so many cents per ton or cubic yard of raw material, and this is the method followed by quarrymen or miners in general. To the cement manufacturer, however, such an estimate is not so suitable as one based on the cost of raw materials per ton or barrel of finished cement.

In the case of hard and comparatively dry limestones or shales, it may be considered that the raw material loses 33⅓ per cent in weight on burning. Converting this relation into pounds of raw material and of clinker we find that 600 pounds of dry raw material will make about four hundred pounds of clinker. Allowing something for other losses in the process of manufacture, it is convenient and sufficiently accurate to estimate that 600 pounds of dry raw material will give one barrel of finished cement. These estimates must be increased if the raw materials carry any appreciable amount of water. Clays will frequently contain 15 per cent or more of water, while soft chalky limestones, if quarried during wet weather, may carry as high as 15 to more than 20 per cent. A Portland cement mixture composed of a pure chalky limestone and a clay might, therefore, average 10 to 20 per cent of water, and consequently about seven hundred pounds of such a mixture would be required to make one barrel of finished cement.

With marls the loss on drying and burning is much greater. Russell states* that according to determinations made by E. D. Campbell, one cubic foot of marl, as it usually occurs in the normal deposits, contains about forty-seven and one-half pounds of lime carbonate and forty-eight pounds of water. In making cement from a mixture of marl and clay, therefore, it would be necessary to figure on excavating and transporting more than one thousand pounds of raw material for every barrel of finished cement.

From the preceding notes it will be understood that the cost of raw materials at the mill, per barrel of cement, will vary not only with the cost of excavation but with the kind of materials in use.

In dealing with hard, dry materials, extracted from open quarries near the mills, the cost of raw materials may vary between eight cents and fifteen cents per barrel of cement. The lower figure named is probably about the lowest attainable with good management and under favorable natural conditions; the higher figure is probably a maximum for fairly careful management of a difficult quarry under eastern labor conditions. When it is necessary to mine the materials, the cost will be somewhat increased. Cement rock has been mined at a cost equivalent to ten cents per barrel of cement, but this figure is attained under particularly favorable conditions. The cost of mining and transportation may reach from this figure up to twenty cents per barrel.

With regard to wet marls and clays, it is difficult to give even an approximate estimate. It seems probable, however, when the dead weight handled is allowed for, that these soft materials will cost almost as much, delivered at the mill, per barrel of finished cement, as the hard dry limestones and shales.

Methods of Manufacture.

If, as in the present discussion, we exclude from consideration the so-called "natural Portlands," Portland cement may be regarded as being an artificial product, obtained by burning to semi-fusion an intimate mixture of pulverized materials, this

*22d Ann. Rept., U. S. Geol. Surv., pt. 3, p. 657.

mixture containing lime, silica and alumina, varying in proportion only within certain narrow limits; and by crushing finely the clinker resulting from this burning.

If this restricted definition of Portland cement be accepted, four points may be regarded as being of cardinal importance in its manufacture. These are:

(1) The cement mixture must be of the proper chemical composition.

(2) The materials of which it is composed must be carefully ground and intimately mixed before burning.

(3) The mixture must be burned at the proper temperature.

(4) After burning, the resulting clinker must be finely ground.

The first named of these points, the chemical composition of the mixture, can be more advantageously discussed after the other three points have been disposed of. The subjects will therefore be taken up in the following order:

Preparation of the mixture for the kiln.

Burning the mixture.

Grinding the clinker, addition of gypsum, etc.

Composition and properties of Portland cement.

PREPARATION OF THE MIXTURE FOR THE KILN.

The preparation of the mixture for the kiln involves the reduction of both of the raw materials to a very fine powder, and their intimate mixture. In practice the raw materials are usually crushed more or less finely, and then mixed, after which the final reduction to powder takes place. Two general methods of treatment, the dry and the wet, are in use at different plants. Unless the limey constituent of the mixture is a marl, already full of water, the dry method is almost invariably followed. This consists merely in keeping the materials in as dry a condition as possible throughout the entire process of crushing and mixing; and, if the raw materials originally contained a little moisture, they are dried before being powdered and mixed. In the wet method, on the other hand, the materials are powdered and mixed while in a very fluid state, containing sixty per cent or more of water.

Drying the raw materials.—With the exception of the marls and clays used in the wet method of manufacture, Portland cement materials are usually dried before the grinding is commenced. This is necessary because the raw materials, as they come from the quarry, pit or mine, will almost invariably carry appreciable, though often very small, percentages of water, which greatly reduces the efficiency of most modern types of grinding mills, and tends to clog the discharge screens.

Percentage of water in raw materials.—The percentage of water thus carried by the crude raw material will depend largely on the character of the material; partly on the method of handling and storing it; and partly on weather conditions.

In the case of hard limestones, freshly quarried, the water will commonly range from ½ to 3 per cent, rarely reaching or exceeding the higher figure except in the very wet quarries or during the rainy season. Such limestones, comparatively dry when quarried, are frequently sent to the grinding mills without artificial drying.

With the soft, chalky limestones, which absorb water very rapidly, the percentage can usually be kept down to 5 per cent or less in dry weather; while prolonged wet weather may necessitate the handling at the mill of material carrying as high as 15 to 20 per cent of water.

The clays present a much more complicated case. In addition to the hydroscopic or mechanically-held water that they may contain, there is also always present a certain percentage of chemically combined water. The amount of hygroscopic water present will depend on the treatment and exposure of the clay; and may vary from 1 per cent or so in clays which have been stored and air dried to as high as 30 per cent in fresh clays. The chemically combined water will depend largely on the composition of the clay, and may vary from 5 to 12 per cent. The hygroscopic or mechanically-held water of clays can be driven off at a temperature of 112 F., while the chemically combined water is lost only at a low red heat. The total water, therefore, to be driven off from clays may range from 6 to 42 per cent, depending on the weather, the drainage of the clay pit, and the care taken in preventing unnecessary exposure to

moisture of the excavated clay. The average total amount of moisture will probably be about 15 per cent.

In dealing with shales, the mechanically-held water will rarely rise above 10 per cent, and can commonly be kept well below that limit. An additional 2 to 7 per cent of water will be carried, by any shale, in a state of chemical combination.

At a few plants marl is used, with clay, in a dry process. As noted elsewhere the marls, as excavated, carry usually about 50 per cent of water. This case presents a more difficult problem than do the other raw materials, because the vegetable matter usually present in marls is extremely retentive of water.

It will be seen, therefore, that cement materials may carry from one per cent to fifty per cent of water when they reach the mill. In a dry process it is necessary to remove practically all of this water before commencing the grinding of the materials. One reason for this is that fine pulverizing can not be economically or satisfactorily accomplished unless absolutely dry material is fed to the grinding machinery. Another reason, which is one of convenience rather than of necessity, is that the presence of water in the raw materials complicates the calculation of the cement mixture.

Methods and costs of drying.—The type of dryer commonly used in cement plants is a cylinder approximately five feet in diameter and forty feet or so in length, set at a slight inclination to the horizontal and rotating on bearings. The wet raw material is fed in at the upper end of the cylinder, and it moves gradually toward the lower end, under the influence of gravity, as the cylinder revolves. In many dryers angle irons are bolted to the interior in such a way as to lift and drop the raw material alternately, thus exposing it more completely to the action of the heated gases, and materially assisting in the drying process. The dried raw material falls from the lower end of the cylinder into an elevator boot, and is then carried to the grinding mills.

The drying cylinder is heated either by a separate furnace or by waste gases from the cement kilns. In either case the products of combustion are introduced into the cylinder at its lower end, are drawn through it, and escape up a stack set at the upper end of the dryer.

The dryer above described is the simplest, and is most commonly used. For handling the small percentages of water contained in most cement materials it is very efficient, but for dealing with high percentages of water, such as are encountered when marl is to be used in a dry process, it seems probable that double heating dryers will be found more economical. This type is exemplified by the Ruggles-Coles dryer. In this dryer a double cylinder is employed. The wet raw material is fed into the space between the inner and outer cylinders, while the heated gases pass first through the inner cylinder, and then, in a reverse direction, through the space betweeen the inner and outer cylinders. This double heating type of dryer is employed in almost all of the slag cement plants in the United States, and is also in use in several Portland cement plants.

When vertical kilns were in use, drying floors and drying tunnels were extensively used, but at present they can be found in only a few plants, being everywhere else supplanted by the rotary dryers.

The cost of drying will depend on the cost of fuel, the percentage of water in the wet material and the type of dryer. Even under the most unfavorable conditions five pounds of water can be expected to be evaporated per pound of coal used, while a good dryer will usually evaporate seven or eight pounds of water per pound of coal.

GRINDING AND MIXING—DRY METHODS.

Part, at least, of the grinding is usually accomplished before the drying, but for convenience the subjects have been separated in the present paper. Usually the limestone is sent through a crusher at the quarry or mill before being dried, and occasionally the raw material is further reduced in a Williams mill, etc., before drying, but the principal part of the reduction always takes place after the material has been dried.

After the two raw materials have been separately dried they may be mixed immediately, or each may be further reduced separately before mixing. Automatic mixers, of which many types are on the market, give a mixture in proportions determined upon from analysis of the materials.

The further reduction of the mixture is usually carried on in two stages, the material being ground to about thirty mesh in a ball mill, komminuter, Griffin mill, etc., and finally reduced in a tube mill. At a few plants, however, single stage reduction is practiced in Griffin or Huntington mills, while at the Edison plant at Stewartsville, New Jersey, the reduction is accomplished in a series of rollers.

The majority of plants use either the Griffin mill and tube mill or the ball and tube mills, and there is probably little difference in the cost of operating these two combinations. The ball mill has never been quite as much of a success as its companion, the tube mill, and has been replaced at several plants by the komminuter

Fineness of mixture.—After its final reduction, and when ready for burning, the mixture will usually run from 90 to 95 per cent through a 100-mesh sieve. In the plants of the Lehigh district the mixture is rarely crushed as fine as when limestone and clay are used. Newberry* has pointed out in explanation for this that an argillaceous limestone (cement rock) mixed with a comparatively small quantity of purer limestone, as in the Lehigh plants, requires less thorough mixing and less fine grinding than when a mixture of limestone and clay (or marl and clay) is used, for even the coarser particles of the argillaceous limestone will vary so little in chemical composition from the proper mixture as to affect the quality of the resulting cement but little, should either mixing or grinding be incompletely accomplished.

A very good example of typical Lehigh Valley grinding of raw material is afforded by a specimen† examined by Prof. E. D. Campbell. This sample of raw mixture ready for burning was furnished by one of the best of the eastern Pennsylvania cement plants. A mechanical analysis of it showed the following results:

*Twentieth Ann. Rept. U. S. Geol. Surv., pt. 6, p. 545.
†Jour. Amer. Chem. Soc., vol. 25, p. 1106.

	Mesh of Sieve.		
	50	100	200
Per cent passing	96 9	85 6	72 4
Per cent residue	3 1	14.4	27.6

The material, therefore, is so coarsely ground that only a trifle over 85 per cent passes a 100-mesh sieve.

GRINDING AND MIXING SLAG-LIMESTONE MIXTURES.

While the manufacture of Portland cement from a mixture of slag and limestone is similar in general theory and practice to its manufacture from a limestone-clay mixture, certain interesting differences occur in the preparation of the mixture. In the following paragraphs the general methods of preparing mixtures of slag and limestone for use in Portland cement manufacture will first be noted, after which certain processes peculiar to the use of this particular mixture will be described separately.

General methods.—After it had been determined that the pozzuolanic cement made* by mixing slag with lime without subsequent burning of the mixture, was not an entirely satisfactory structural material, attention was soon directed toward the problem of making a true Portland cement from such a slag. The blast-furnace slags commonly available, while carrying enough silica and alumina for a cement mixture, are too low in lime to be suitable for Portland cement. Additional lime must be added, usually in the form of limestone, the slag and limestone must be well mixed and the mixture properly burned. The general methods for accomplishing the proper mixture of the materials vary in details. It seems probable that the first method used in attempting to make a true Portland cement from slag, was to dump the proper proportion of limestone, broken into small lumps, into molten slag. The idea was that both mixing and calcination could thus be accomplished in one stage; but in practice it was found that the resulting cement was variable in composition and always low

*See Municipal Engineering, vol. 24, p. 335, May, 1903.

in grade. This method has accordingly fallen into disuse, and at present three different general processes of preparing the mixture are practiced at different European and American plants.

(1) The slag is granulated, dried, and ground, while the limestone is dried and ground separately. The two materials are then mixed in proper proportions, the mixture is finely pulverized in tube mills, and the product is fed in a powdered state to rotary kilns.

(2) The slag is granulated, dried, and mixed with slightly less than the calculated proper amount of limestone, which has been previously dried and powdered. To this mixture is added sufficient powdered slaked lime (about 2 to 6 per cent) to bring the mixture up to the correct composition. The intimate mixture and final reduction are then accomplished in ball and tube mills. About 8 per cent of water is then added, and the slurry is made into bricks, which are dried and burned in a dome or chamber kiln.

(3) Slag is granulated and mixed, while still wet, with crushed limestone in proper proportions. This mixture is run through a rotary calciner, heated by waste kiln gases, in which the temperature is sufficient not only to dry the mixture, but also to partly powder it, and to reduce most of the limestone to quicklime. The mixture is then pulverized and fed into rotary kilns.

Of the three general processes above described the second is unsuited to American conditions. The first and third are adapted to the use of the rotary kiln. The third seems to be the most economical, and has given remarkably low fuel consumption in practice, but so far has not been taken up in the United States.

Certain points of manufacture peculiar to the use of mixtures of slag and limestone will now be described.

Composition of the slag.—The slags available for use in Portland cement manufacture are of quite common occurrence in iron-producing districts. Those best suited for such use are the more basic blast-furnace slags, and the higher such slags run in lime the more available they are for this use. The slags utilized will generally run from 30 to 40 per cent lime.

The presence of more than 3 per cent or so of magnesia in a slag is of course enough to render its use as a Portland cement material inadvisable; and on this account slags from furnaces using dolomite (magnesian limestone) as a flux, are unsuited for cement manufacture. The presence of any notable percentage of sulphur is also a drawback, though, as will be later noted, part of the sulphur in the slag will be removed during the processes of manufacture.

Granulation of slag.—If slag be allowed to cool slowly it solidifies into a dense, tough material, which is not readily reduced to the requisite fineness for a cement mixture. If it be cooled suddenly, however, as by bringing the stream of molten slag into contact with cold water, the slag is "granulated," i. e., it breaks up into small porous particles. This granulated slag or "slag sand" is much more readily pulverized than a slowly cooled slag; its sudden cooling has also intensified the chemical activity of its constituents so as to give it hydraulic properties, while part of the sulphur contained in the original slag has been removed. The sole disadvantage of the process of granulating slag is that the product contains 20 to 40 per cent of water, which must be driven off before the granulated slag is sent to the grinding machinery.

In practice the granulation of the slag is effected by directing the stream of molten slag direct from the furnace into a sheet-iron trough. A small stream of water flows along this trough, the quantity and rate of flow of water being regulated so as to give complete granulation of the slag without using an excessive amount of water. The trough may be so directed as to discharge the granulated slag into tanks or into box cars, which are usually perforated at intervals along the sides so as to allow part of the water to drain off.

Drying the slag.—As above noted, the granulated slag may carry from 20 to 40 per cent of water. This is removed by treating the slag in rotary driers. In practice such driers give an evaporation of eight to ten pounds of water per pound of coal. The practice of slag drying is very fully described in Vol. 10 of the Mineral Industry, pages 84-95, where figures and descriptions of various driers are also given, with data on their evapo-

rative efficiency. As noted earlier in this article, one of the methods of manufacturing Portland cement from slags puts off the drying of the slag until after it has been mixed with the limestone, and then accomplishes the drying by utilizing waste heat from the kilns. Kiln gases could of course be used anyway in the slag driers, but it so happens that they have not been so used except in plants following the method in question.

Grinding the slag.—Slag can be crushed with considerable ease to about 50-mesh, but notwithstanding its apparent brittleness it is difficult to grind it finer. Until the introduction of the tube mill it was almost impossible to reduce this material to the fineness necessary for a cement mixture, and the proper grinding of the slag is still an expensive part of the process as compared with the grinding of limestone, shales or clay.

Composition of the limestone.—As the slag carries all the silica and alumina necessary for the cement mixture, the limestone to be added to it should be simply a pure lime carbonate. The limestone used for flux at the furnace which supplies the slag will usually be found to be of suitable composition for use in making up the cement mixture.

ECONOMICS OF USING SLAG-LIMESTONE MIXTURES.

The manufacture of a true Portland cement from a mixture of slag and limestone presents certain undoubted advantages over the use of any other raw materials, while it has also a few disadvantages.

Probably the most prominent of the advantages lies in the fact that the most important raw material—the slag—can usually be obtained more cheaply than an equal amount of natural raw material could be quarried or mined. The slag is a waste product, and a troublesome material to dispose of, for which reasons it is obtained at small expense to the cement plant. Another advantage is due to the occurrence of the lime in the slag as oxide, and not as carbonate. The heat necessary to drive off the carbon dioxide from an equivalent mass of limestone is therefore saved when slag forms part of

the cement mixture, and very low consumption is obtained when slag-limestone mixture is burned.

Of the disadvantages, the toughness of the slag and the necessity for drying it before grinding are probably the most important. These serve to partly counterbalance the advantages noted above. A third difficulty, which is not always apparent at first, is that of securing a proper supply of suitable slag. Unless the cement plant is closely connected in ownership with the furnaces from which its slag supply is to be obtained, this difficulty may become very serious. In a season when a good iron market exists the furnace manager will naturally give little thought to the question of supplying slag to an independent cement plant.

The advantages of the mixture, however, seem to outweigh its disadvantages, for the manufacture of Portland cement from slag is now a large and growing industry in both Europe and America. Two Portland cement plants using slag and limestone as raw materials have been established for some time in this country, several others are in course of construction at present, and it seems probable that in the near future Alabama will join Illinois and Pennsylvania as an important producer of Portland cement from slag.

GRINDING AND MIXING.—WET METHODS.

Wet methods of preparing Portland cement mixtures date back to the time when millstones and similar crude grinding contrivances were in use. With such imperfect machinery it was impossible to grind dry materials fine enough to give a a good Portland cement mixture. The advent of good grinding machinery has practically driven out wet methods of manufacture in this country, except in dealing with materials such as marls, which naturally carry a large percentage of water. One or two plants in the United States do, it is true, deliberately add water to a limestone-clay mixture; but the effect of this practice on the cost sheets of these remarkable plants is not encouraging.

In preparing cement mixtures from marl and clay, a few plants dry both materials before mixing. It seems probable

that this practice will spread, for the wet method of mixture is inherently expensive. At present, however, almost all marl plants use wet methods of mixing, and it is therefore necessary to give some space to a discussion of such methods.

Certain points regarding the location, physical condition, and chemical composition of the marls and clays used in such mixtures have important effects upon the cost of the wet process. As regards location, considered on a large scale, it must be borne in mind that marl deposits of workable size occur only in the Northern States and in Canada. In consequence the climate is unfavorable to continuous working throughout the year, for the marl is usually covered with water, and in winter it is difficult to secure the material. In a minor sense location is still an important factor, for marl deposits necessarily and invariably are found in depressions; and the mill must, therefore, just as necessarily, be located at a higher level than its source of raw material, which involves increased expense in transporting the raw material to the mill.

Glacial clays, which are usually employed in connection with marl, commonly carry a much larger proportion of sand and pebbles than do the sedimentary clays of more southerly regions.

The effect of the water carried by the marl has been noted in an earlier paper. The material as excavated will consist approximately of equal weights of lime carbonate and of water. This, on the face of it, would seem to be bad enough as a business proposition; but we find that in practice more water is often added to permit the marl to be pumped to the mill.

On the arrival of the raw materials at the mill the clay is often dried, in order to simplify the calculation of the mixture. The reduction of the clay is commonly accomplished in a disintegrator or in edge-runner mills, after which the material is further reduced in a pug mill, sufficient water being here added to enable it to be pumped readily. It is then ready for mixture with the marl, which at some point in its course has been screened to remove stones, wood, etc., as far as possible. The slurry is further ground in pug mills or wet grinding mills

of the disk type; while the final reduction takes place commonly in wet tube mills. The slurry, now containing 30 to 40 per cent of solid matter and 70 to 60 per cent of water, is pumped into storage tanks, where it is kept in constant agitation to avoid settling. Analyses of the slurry are taken at this point, and the mixture in the tanks is corrected if found to be of unsatisfactory composition. After standardizing, the slurry is pumped into the rotary kilns. Owing to the large percentage of water contained in the slurry the fuel consumption per barrel of finished cement is 30 to 50 per cent greater, and the output of each kiln correspondingly less than in the case of a dry mixture. This point will, however, be further discussed in the next article of this series.

It may be of interest, for comparison with the above description of the wet process with rotary kilns, to insert a description of the semi-wet process as carried on a few years ago at the dome kiln plant of the Empire Portland Cement Company of Warners, N. Y. The plant has been remodeled since that date, but the processes formerly followed are still of interest, as they resulted in a high grade though expensive product.

At the Empire plant the marl and clay are obtained from a swamp about three-fourths of a mile from the mill. A revolving derrick with clam-shell bucket was employed for excavating the marl, while the clay was dug with shovels. The materials are taken to the works over a private narrow-gage road, on cars carrying about three tons each, drawn by a small locomotive. At the mill the cars were hauled up an inclined track, by means of a cable and drum, to the mixing floor.

The clay was dried in the Cummer "salamander" driers, after which it was allowed to cool, and then carried to the mills. These mills were the Sturtevant "rock emery" type, and reduced the clay to a fine powder, in which condition it was fed, after being weighed, to the mixer. The marl was weighed and sent directly to the mixer, no preliminary treatment being necessary. The average charge was about 25 per cent clay and about 75 per cent marl.

The mixing was carried on in a mixing pan twelve feet in diameter, in which two large rolls, each about five feet in diameter and

sixteen-inch face, ground and mixed the materials thoroughly. The mixture was then sampled and analyzed, after which it was carried by a belt conveyor to two pug mills, where the mixing was completed and the slurry formed into slabs about three feet long and four to five inches in width and height. These on issuing from the pug mill were cut into a number of sections so as to give bricks about six inches by four inches by four inches in size. The bricks were then placed on slats, which were loaded on rack cars and run into the drying tunnels. The tunnels were heated by waste gases from the kilns and required from twenty-four to thirty-six hours to dry the bricks.

After drying, the bricks were fed into dome kilns, twenty of which were in use, being charged with alternate layers of coke and slurry bricks. The coke charge for a kiln was about four or five tons, and this produced twenty to twenty-six tons of clinker at each burning, thus giving a fuel consumption of about 20 per cent, as compared with the 40 per cent or so required in the rotary kilns using wet materials. From thirty-six to forty hours were required for burning the charge. After cooling, the clinker was shoveled out, picked over by hand, and reduced in a Blake crusher, Smidth ball mills, and Davidsen tube mills.

Composition of mixture.—The cement mixture ready for burning will commonly contain from 74 to 77.5 per cent of lime carbonate, or an equivalent proportion of lime oxide. Several analyses of actual cement mixtures are given in the following table. Analysis No. 1, with its relatively high percentage of magnesia, is fairly typical of Lehigh Valley practice. Analyses Nos. 2 and 3 show mixtures low in lime, while analysis No. 4 is probably the best proportion of the four, especially in regard to the ratio between silica and alumina plus iron. This ratio, for ordinary purposes, should be about 3:1, as the cement becomes quicker setting and lower in ultimate strength as the percentage of alumina increases. If the alumina percentage be carried too high, moreover, the mixture will give a fusible, sticky clinker when burned, causing trouble in the kilns.

ANALYSES OF CEMENT MIXTURES.

	1	2	3	4
Silica	12.62	13.46	13.85	14.77
Alumina and iron oxide	6.00	?	7.20	4.35
Carbonate of lime	75.46	73.66	73.93	76.84
Magnesium oxide	2.65	?	?	1.74

BURNING THE MIXTURE

After the cement mixture has been carefully prepared, as described in preceding pages, it must be burned with equal care. In the early days of the industry a simple vertical kiln, much like that used for burning lime and natural cement, was used for burning the Portland cement mixture. These kilns, while fairly efficient so far as fuel consumption was concerned, were expensive in labor, and their daily output was small. In France and Germany they were soon supplanted by improved types, but still stationary and vertical, which gave very much lower fuel consumption. In America, however, where labor is expensive while fuel is comparatively cheap, an entirely different style of kiln has been evolved. This is the rotary kiln With the exception of a very few of the older plants, which have retained vertical kilns, all American Portland cement plants are now equipped with rotary kilns.

The history of the gradual evolution of the rotary kiln is of great interest, but as the subject can not be taken up here, reference should be made to the papers cited below* in which details, accompanied often by illustrations of early types of rotary kilns, are given.

*Duryee, E., The first manufacture of Portland cement by the direct rotary kiln process. Engineering News, July 26, 1900.

Leslie, R. W., History of the Portland cement industry in the United States, 146 pages, Philadelphia, 1900.

Lewis, F. H., The American rotary kiln process for Portland cement, in the Cement Industry, pp. 188-199, New York, 1900.

Matthey, H., The invention of the new cement burning method. Engineering and Mining Journal, Vol. 67, pp. 555, 705, 1899.

Stanger, W. H., and Blount, B., The rotary process of cement manufacture. Proc. Institution Civil Engineers, Vol. 145, pp. 44-136, 1901.

Editorial, The influence of the rotary kiln on the development of Portland cement manufacture in America. Engineering News, May 3, 1900.

The design, construction and operation of the vertical stationary kilns of various types is discussed in many reports on Portland cement, the most satisfactory single paper being probably that referred to below.* As the subject is, in America at least, a matter of simply historical interest, no description of these kilns or their operation will be given in the present paper.

At present, practice in burning at the different American cement plants is rapidly approaching uniformity, though difference in materials, etc., will always prevent absolute uniformity from being reached. The kiln in which the material is burned is now almost invariably of the rotary type, the rotary process which is essentially American in its development, being based upon the substitution of machines for hand labor wherever possible. A brief summary of the process will first be given, after which certain subjects of interest will be taken up in more detail.

SUMMARY OF BURNING PROCESS.

As at present used, the rotary kiln is a steel cylinder about six feet in diameter; its length, for dry materials, has usually been sixty feet, but during the past year many eighty-foot kilns have been built, while for wet mixtures an eighty-foot, or even longer, kiln is frequently employed.

This cylinder is set in a slightly inclined position, the inclination being approximately one-half inch to the foot. The kiln is lined, except near the upper end, with very resistant fire brick, to withstand both the high temperature to which its inner surface is subjected and also the destructive action of the molten clinker.

The cement mixture is fed in at the upper end of the kiln, while fuel (which may be either powdered coal, oil, or gas) is injected at its lower end. The kiln, which rests upon geared bearings, is slowly revolved about its axis. This revolution, in connection with the inclination at which the cylinder is set, gradually carries the cement mixture to the lower end of the

*Stanger, W. H., and Blount, B., Gilbert, W., and Candlot, E. (Discussion of the value, design and results obtained from various types of fixed kilns.) Proc. Institution Civil Engineers, Vol. 145, pp. 44, 48, 81, 82, 99, 100. 1901.

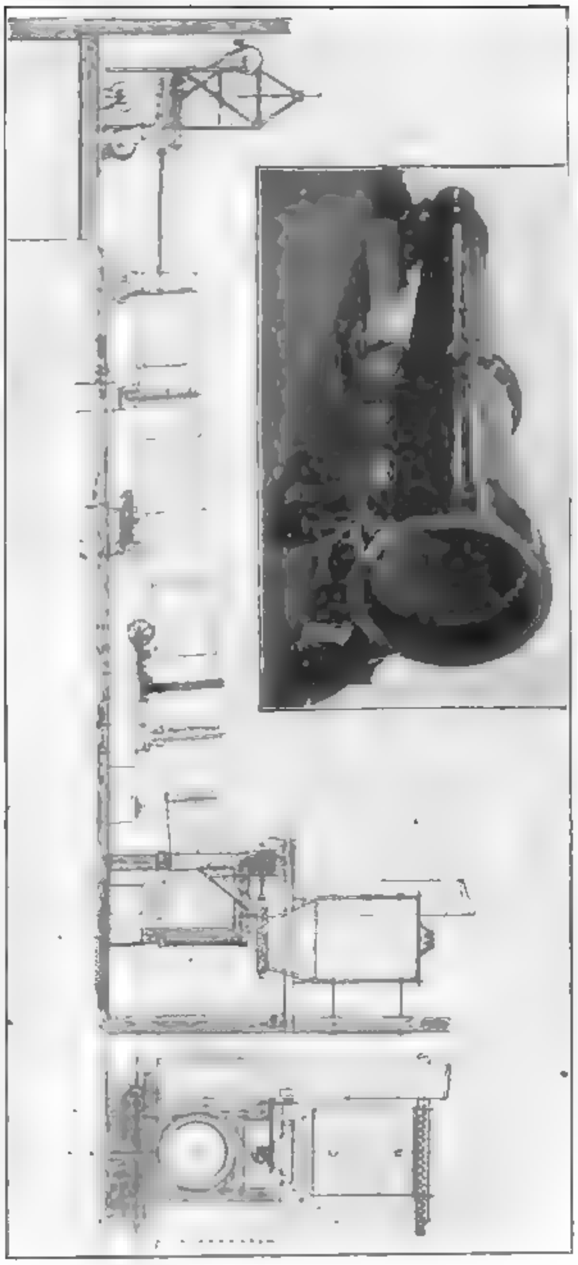

PLATE III. View of the Rotary Kiln, also showing method of firing with powdered coal under blast.

kiln. In the course of this journey the intense heat generated by the burning fuel first drives off the water and carbon dioxide from the mixture, and then causes the lime, silica, alumina and iron to combine chemically to form the partially fused mass known as "cement clinker." This clinker drops out of the lower end of the kiln, is cooled so as to prevent injury to the grinding machinery, and is then sent to the grinding mills.

THEORETICAL FUEL REQUIREMENTS.

As a preliminary to a discussion of actual practice in the matter of fuel, it will be of interest to determine the heat units and fuel theoretically required in the manufacture of Portland cement from a dry mixture of normal composition.

In burning such a mixture to a clinker, practically all of the heat consumed in the operation will be that required for the dissociation of the lime carbonate present into lime oxide and carbon dioxide. Driving off the water of combination that is chemically held by the clay or shale, and decomposing any calcium sulphate (gypsum) that may be present in the raw materials, will require a small additional amount of heat. The amount required for these purposes is not accurately known, however, but is probably so small that it will be more or less entirely offset by the heat which will be liberated during the combination of the lime with the silica and alumina. We may, therefore, without sensible error, regard the total heat theoretically required for the production of a barrel of Portland cement as being that which is necessary for the dissociation of 450 pounds of lime carbonate. With coal of a thermal value of 13,500 B. T. U., burned with only the air supply demanded by theory this dissociation will require 25½ pounds of coal per barrel of cement, a fuel consumption of only 6.6 per cent.

Losses of heat in practice.—In practice with the rotary kiln, however, there are a number of distinct sources of loss of heat, which result in a fuel consumption immensely greater than the theoretical requirements given above. The more important of these sources of loss are the following:

1. The kiln gases are discharged at a temperature much above that of the atmosphere, ranging from 300° F. to 2,000° F.,

according to the type of materials used and the length of the kiln.

2. The clinker is discharged at a temperature varying from 300° F. to 2,500° F., the range depending, as before, on materials and length of the kiln.

3. The air supply injected into the kiln is always greater, and usually very much greater, than that required for the perfect combustion of the fuel; and the available heating power of the fuel is thereby reduced.

4. Heat is lost by radiation from the ends and exposed surfaces of the kiln.

5. The mixture, in plants using a wet process, carries a high percentage of water, which must be driven off.

It is evident, therefore, that present-day working conditions serve to increase greatly the amount of fuel actually necessary for the production of a barrel of cement above that required by theory.

Actual fuel requirements and output.—Rotary kilns are nominally rated at a production of 200 barrels per day per kiln. Even on dry and easily clinkered materials and with good coal, however, such an output is not commonly attained. Normally a kiln working a dry mixture will produce from 160 to 180 barrels of cement per day of twenty-four hours. In doing this, if good coal is used its fuel consumption will commonly be from 120 to 140 pounds of coal per barrel of cement, though it may range as high as 160 pounds, and, on the other hand, has fallen as low as 90 pounds. An output of 175 barrels per day, with a coal consumption of 130 pounds per barrel, may therefore be considered as representing the results of fairly good practice on dry materials. In dealing with a wet mixture, which may carry anywhere from 30 to 70 per cent of water, the results are more variable, though always worse than with dry materials. In working a sixty-foot kiln on a wet material, the output may range from 80 to 140 barrels per day, with a fuel consumption of from 150 to 230 pounds per barrel. Using a longer kiln, partly drying the mixture, and utilizing waste heat, will of course improve these figures materially.

When the heavy Western oils are used for kiln fuel, it may be considered that one gallon of oil is equivalent in the kiln to about ten pounds of coal. The fuel consumption, using dry materials will range between eleven and fourteen gallons of oil per barrel of cement; but the output per day is always somewhat less with oil fuel than where coal is used.

Natural gas in the kiln may be compared with good Pennsylvania coal by allowing about 20,000 to 30,000 cubic feet of gas as equivalent to a ton of coal. This estimate is, however. based upon too little data to be as close as those above given for oil or coal.

Effect of composition on burning.—The differences in composition between Portland cement mixtures are very slight if compared, for example, to the differences between various natural cement rocks. But even such slight differences as do exist exercise a very appreciable effect on the burning of the mixture. Other things being equal, any increase in the percentage of lime in the mixture will necessitate a higher temperature in order to get an equally sound cement. A mixture which will give a cement carrying 59 per cent of lime, for example, will require much less thorough burning than would a mixture designed to give a cement with 64 per cent of lime.

With equal lime percentages, the cement carrying high silica and low alumina and iron will require a higher temperature than if it were lower in silica and higher in alumina and iron. But, on the other hand, if the alumina and iron are carried too high, the clinker will ball up in the kiln, forming sticky and unmanageable masses.

Character of kiln coal.—The fuel most commonly used in modern rotary kiln practice is bituminous coal, pulverized very finely. Coal for this purpose should be high in volatile matter, and as low in ash and sulphur as possible. Russell gives the following analyses of West Virginia and Pennsylvania coals used at present at various cement plants in Michigan.

ANALYSES OF KILN COALS.

	1	2	3	4
Fixed carbon	56.15	56.33	55.82	51.69
Volatile matter	35.41	35.26	39.37	39.52
Ash	6.36	7.06	3.81	6.13
Moisture	2 08	1.35	1.00	1.40
Sulphur	1.30	1.34	0.42	1.46

The coal as usually bought is either "slack" or "run of mine." In the latter case it is necessary to crush the lumps before proceeding further with the preparation of the coal, but with slack this preliminary crushing is not necessary, and the material can go directly to the dryer.

Drying coal.—Coal as bought may carry as high as 15 per cent of water in winter or wet season. Usually it will run from 3 to 8 per cent. To secure good results from the crushing machinery it is necessary that this water should be driven off. For coal drying, as for the drying of raw materials, the rotary dryer seems best adapted to American conditions. It should be said, however, that in drying coal it is usually considered inadvisable to allow the products of combustion to pass through the cylinder in which the coal is being dried. This restriction serves to decrease slightly the possible economy of the dryer, but an evaporation of six to eight pounds of water per pound of fuel coal can still be counted on with any good dryer. The fuel cost of drying coal containing 8 per cent of moisture, allowing $2 per ton for the coal used as fuel, will therefore be about three to four cents per ton of dried product.

Pulverizing coal.—Though apparently brittle enough when in large lumps, coal is a difficult material to pulverize finely. For cement kiln use, the fineness of reduction is very variable. The finer the coal is pulverized the better results will be obtained from it in the kiln; and the poorer the quality of the coal the finer it is necessary to pulverize it. The fineness attained in practice may therefore vary from 85 per cent, through a 100-mesh sieve, to 95 per cent or more, through the same. At one plant a very poor but cheap coal is pulverized to pass 98 per

cent through a 100-mesh sieve, and in consequence gives very good results in the kiln.

Coal pulverizing is usually carried on in two stages, the material being first crushed to 20 to 30-mesh in a Williams mill or ball mill, and finally reduced in a tube mill. At many plants, however, the entire reduction takes place in one stage, Griffin or Huntington mills being used.

Total cost of coal preparation.—The total cost of crushing (if necessary), drying and pulverizing coal, and of conveying and feeding the product to the kiln, together with fair allowances for replacements and repairs, and for interest on the plant, will probably range from about twenty to thirty cents per ton of dried coal, for a 4-kiln plant. This will be equivalent to a cost of from three to five cents per barrel of cement. While this may seem a heavy addition to the cost of cement manufacture, it should be remembered that careful drying and fine pulverizing enable the manufacturer to use much poorer—and therefore cheaper—grades of coal than could otherwise be utilized.

CLINKER GRINDING.

The power and machinery required for pulverizing the clinker at a Portland cement plant using the dry process of manufacture is very nearly the same as that required for pulverizing the raw materials for the same output. This may seem, at first sight, improbable, for Portland cement clinker is much harder to grind than any possible combination of raw materials; but it must be remembered that for every barrel of cement produced about 600 pounds of raw materials must be pulverized, while only a scant 400 pounds of clinker will be treated, and that the large crushers required for some raw materials can be dispensed with in crushing clinker. With this exception, the raw material side and the clinker side of a dry-process Portland cement plant are usually almost or exactly duplicates.

The difficulty, and in consequence the expense, of grinding clinker will depend in large part on the chemical composition of the clinker and on the temperature at which it has been burned. The difficulty of grinding, for example, increases with the percentage of lime carried by the clinker; and a clinker

containing 64 per cent of lime will be very noticeably more resistant to pulverizing than one carrying 62 per cent of lime. So far as regards burning, it may be said in general that the more thoroughly burned the clinker the more difficult it will be to grind, assuming that its chemical composition remains the same.

The tendency among engineers at present is to demand more finely ground cement. While this demand is doubtless justified by the results of comparative tests of finely and coarsely ground cements, it must be borne in mind that any increase in fineness of grinding means a decrease in the product per hour of the grinding mills employed, and a consequent increase in the cost of cement. At some point in the process, therefore, the gain in strength due to fineness of grinding will be counterbalanced by the increased cost of manufacturing the more finely ground product.

The increase in the required fineness has been gradual but steady during recent years. Most specifications now require at least 90 per cent to pass a 100-mesh sieve; a number require 92 per cent; while a few important specifications require 95 per cent. Within a few years it is probable that almost all specifications will go as high as this.

ADDITION OF GYPSUM.

The cement produced by the rotary kiln is invariably naturally so quick-setting as to require the addition of sulphate of lime. This substance, when added in quantities up to 2½ or 3 per cent, retards the rate of set of the cement proportionately, and appears to exert no injurious influence on the strength of the cement. In amounts above 3 per cent, however, its retarding influence seems to become at least doubtful, while a decided weakening of the cement is noticeable.

Sulphate of lime may be added in one of two forms; either as crude gypsum or as burned plaster. Crude gypsum is a natural hydrous lime sulphate, containing about 80 per cent of lime sulphate and 20 per cent of water. When gypsum is calcined at temperatures not exceeding 400° F., most of its contained water is driven off. The "plaster" remaining carries about 93 per cent of lime sulphate, with only 7 per cent of water.

In Portland cement manufacture either gypsum or burned plaster may be used to retard the set of the cement. As a matter of fact, gypsum is the form almost universally employed in the United States. This is merely a question of cost. It is true, that to secure the same amount of retardation of set it will be necessary to add a little more of gypsum if burned plaster were used; but, on the other hand, gypsum is much cheaper than burned plaster.

The addition of the gypsum to the clinker is usually made before it has passed into the ball mill, komminuter, or whatever mill is in use for preliminary grinding. Adding it at this point secures much more thorough mixing and pulverizing than if the mixture were made later in the process. At some of the few plants which use plaster instead of gypsum, the finely ground plaster is not added until the clinker has received its final grinding and is ready for storage or packing.

Constitution of Portland Cement.

During recent years much attention has been paid by various investigators to the constitution of Portland cement. The chemical composition of any particular sample can, of course, be readily determined by analysis; and by comparison of a number of such analyses, general statements can be framed as to the range in composition of good Portland cements.

The chemical analysis will determine what ingredients are present, and in what percentages, but other methods of investigation are necessary to ascertain in what manner these various ingredients are combined. A summary only of the more important results brought out by these investigations on the constitution of Portland cement will be given in this place.

It would seem to be firmly established that, in a well burned Portland cement, much of the lime is combined with most of the silica to form the compound $3CaO, SiO_2$,—tricalcic silicate. To this compound is ascribed, in large measure, the hydraulic properties of the cement, and in general it may be said that the value of a Portland cement increases directly as the proportion of $3CaO, SiO_2$. The ideal Portland cement, toward which cements as actually made tend in composition, would consist

exclusively of tricalcic silicate, and would be, therefore, composed entirely of lime and silica, in the following proportions:

Lime (CaO)	73.6
Silica (SiO_2)	26.4

Such an ideal cement, however, can not be manufactured under present commercial conditions, for the heat required to clinker such a mixture can not be attained in any working kiln. Newberry has prepared such mixtures by using the oxy-hydrogen blowpipe; and the electrical furnace will also give clinker of this composition; but a pure lime-silica Portland is not possible under present day conditions.

In order to prepare Portland cement in actual practice, therefore, it is necessary that some other ingredient or ingredients should be present to serve as a flux in aiding the combination of the lime and silica, and such aid is afforded by the presence of alumina and iron oxide.

Alumina (Al_2O_3) and iron oxide (Fe_2O_3), when present in noticeable percentages, serve to reduce the temperature at which combination of the lime and silica (to form $3CaO, SiO_2$) takes place; and this clinkering temperature becomes further and further lowered as the percentages of alumina and iron are increased. The strength and value of the product, however, also decrease as the alumina and iron increase; so that in actual practice it is necessary to strike a balance between the advantage of low clinkering temperature and the disadvantage of weak cement, and to thus determine how much alumina and iron should be used in the mixture. This point will be further discussed in later pages.

It is generally considered that whatever alumina is present in the cement is combined with part of the lime to form the compound $2CaO, Al_2O_3$,—dicalcic aluminate. It is also held by some, but this fact is somewhat less firmly established than the last, that the iron present is combined with the lime to form the compound $2CaO, Fe_2O_3$. For the purposes of the present paper it will be sufficient to say that, in the relatively small percentages in which iron occurs in Portland cement, it may for convenience be considered as entirely equivalent to alumina

and its action, and the two may be calculated together. When alumina is named in this paper, therefore, it will be understood to include any iron that may be present.

CEMENT MATERIALS IN IOWA.

BY H. FOSTER BAIN.

General Statement.

Materials capable of furnishing the silica and alumina necessary to the manufacture of Portland cement are widespread, and the location of new plants is apt to be determined by the presence of suitable calcareous deposits and favorable industrial conditions. Iowa affords no exception to these general rules. In practically all parts of the state there are shales or clays which might if necessary be used as one of the constituents of a cement mixture. The indurated rocks from the Ordovician to the Cretaceous afford shales of wide distribution and excellent character. The surface formations supplement these resources with loess, alluvium, and certain minor bodies of water-laid clay of glacial derivation. The shales and the clays have been extensively studied and a special report upon them by Dr. S. W. Beyer was published in 1904. For present purposes it will suffice to say that such material suitable for use in the manufacture of Portland cement can be found at almost every point in the state where other conditions are favorable to its production.

The calcareous constituent of cements is most commonly derived from marls, chalk and limestone. All these occur within the state though they are of very unequal importance.

CALCAREOUS MARLS.

Marls are extensively used at several points in the United States in the manufacture of cement. The large cement in-

dustry of Michigan in particular is founded upon the occurrence within that state of extensive deposits of calcareous marl in the shallow lakes of the lower peninsula*. Similar marls are used in New Jersey and Ohio. The lakes in which the marl occurs are located within the area covered by the Wisconsin drift, and similar lakes are particularly characteristic of such areas. In Iowa the north central portion of the state is covered by drift of Wisconsin age† and is dotted with small shallow lakes resembling in appearance and genesis those of Michigan. From time to time small amounts of marl have been reported from this area and while so far no bodies of commercial importance have been located it is not impossible that such may be found.

CHALK DEPOSITS.

The Cretaceous deposits which cover the western third of Iowa include important bodies of chalk. With but two exceptions, both of which are unimportant, outcrops of the chalk beds are confined to the valley of the Big Sioux river between Sioux City and Hawarden. The chalk beds received some attention in the course of the early geological surveys of the region and have been recently restudied by Calvin, ‡ Bain § and Wilder ||.

The chalk forms prominent bluffs at intervals and may be well seen near Westfield, Akron and Hawarden. It was referred to the Niobrara formation until Wilder discovered fossils characteristic of the Benton in the shale above. This proves it to be the equivalent of the "Oyster Shell Rim" of the Black Hills or the Graneros limestone. A thickness of twenty to thirty feet is ordinarily seen in individual exposures, but a total thickness of fifty feet is probably present. A generalized section may be given as follows:

* Russell, I. C., Portland Cement Industry in Michigan, 22nd Ann. Rept. U. S. Geol. Surv., pt. iii, pp. 685-685.

†See Plate ii. Iowa Geol. Surv., Vol. XI, 1900.

‡ Calvin, S., Cretaceous Deposits of Woodbury and Plymouth Counties, etc., Iowa Geol. Surv., Vol. I, pp. 147-161, 1893.

§ Bain, H. F., Cretaceous Deposits of the Sioux Valley, Iowa Geol. Surv., Vol. III, pp. 101-114, 1895; Geology of Woodbury County, Ibid, Vol. V., pp. 278-275, 295-296, 1896; Geology of Plymouth County, Ibid, Vol. VIII, pp. 354-360, 1898.

|| Wilder, F. A., Geology of Lyon and Sioux Counties, Iowa Geol. Suv., Vol. X, pp. 111-115, 151-152 1900.

Section of Chalk Beds.

		FEET.
3.	Chalk	4 to 6
2.	Limestone, soft, splitting into thin slabs and crowded with shells of Inoceramus	12
1.	Chalk	12

The interbanding of thin bedded limestone and the chalk is quite characteristic. Both materials are soft and grind easily. Almost no magnesia is present, as is shown by the following analyses, and in some instances the chalk beds themselves carry enough or more than enough clay to make a good cement mixture. In all cases excellent clays occur immediately above or below. The clays are now being used at Sioux City and elsewhere in the manufacture of a wide variety of clay products.

Analyses of Iowa Chalks.

	I	II	III
Silica and insol. mat	22.70	....	....
Iron and alumina (oxides)	6.68	....	....
Calcium carbonate	64.30	83.70	94.39
Magnesium carbonate	5.38	2.48	.70
Water	....	.08	.06

I. Chalk rock, Hawarden, Iowa...............Newberry Anal.
II. Chalk rock, Westfield, Iowa..................Weems Anal.
III. Chalk rock, Le Mars, Iowa..................Weems. Anal.

It is evident that materials suitable for the manufacture of Portland cement are available, and this conclusion is confirmed by the fact that at Yankton, S. D., a plant has for many years been in operation in which similar beds, belonging to the Niobrara, are used. Furthermore, in tests carried on at Sioux City cement has been made experimentally from the local material.*

LIMESTONES.

General statement.—Non-magnesian limestones are found in Iowa in the Ordovician, Devonian, and Carboniferous. The

*Lonsdale, E. H., Proc. Iowa Acad. Sci., Vol. II, p. 178, 1895.

limestones of the Cambrian and Silurian are without important exception highly magnesian. Those of the Ordovician are predominantly magnesian, though an exception occurs in the case of the beds which it has been customary to map and discuss under the name Trenton. In eastern Iowa the dolomites and magnesian limestones have heretofore attracted more attention than the non-magnesian rocks, and flourishing lime and building stone industries have been founded upon them. Limestone of one class or the other occurs in all of the eastern and most of the southern counties. In the northwest the covering of Cretaceous and Pleistocene deposits limits the outcrops to a few deep stream valleys. The general distribution of the geological formations of the state is shown in plate II of volume XIV of the present series of reports. For details of localities the reader is referred to the various county reports of the Iowa Geological Survey cited in this text. The transportation facilities available at each point may be best learned from the large map of the state published and distributed gratuitously by the Railway Commissioners.

ORDOVICIAN LIMESTONES.

Below the Devonian there is but one limestone outcropping in Iowa which is at all suitable for Portland cement manufacture. It is known as the Trenton, and occupies portions of Dubuque, Clayton, Fayette, Winneshiek and Allamakee counties.* Under this name have been included and mapped an aggregate of non-magnesion limestones and thin shales, varying in thickness from fifteen to three hundred and fifty feet. The variation in thickness is an expression of the fact that the difference between the Galena and Trenton is lithologic and not formational. It is probable that in the future the division will be made upon some other basis, but for present purposes the lithologic difference is the important one. The strata included on this basis within the Trenton are in the main either non-magnesian or only slightly magnesian. In composition as in geologic position they are almost exactly equivalent to the

*Reports on the geology of Fayette, Winneshiek and Clayton counties are now in preparation. For the geology of Allamakee county, see Iowa Geol. Surv., Vol. IV, pp. 85-120; for Dubuque county, see Ibid, Vol. X, pp. 379-651.

famous cement rock of the Lehigh Valley, from which 60 per cent of the Portland cement production of the United States now comes.

Excellent exposures of the Trenton occur along the Mississippi river and its tributaries in the counties named above. At Specht Ferry, in Dubuque county, the following section was observed.

Specht Ferry Section.

		FEET.
13.	Thin-bedded, brown dolomite, with shaly partings (Galena)	4
12.	Thin-bedded, imperfectly dolomitized limestone, with fossil brachiopod shells only slightly changed; the limestone brown, earthy, noncrystalline, but evidently of the Galena type.	3
11.	Thick, earthy, imperfectly dolomitized beds (Galena)	3
10.	Thin limestone beds with much shale in the partings; in part a true shale	5
9.	Limestone, bluish, rather coarse-grained, with few fossils	4
8.	Limestone similar to above	3
7.	Limestone similar to above	18
6.	Shale, bluish or greenish, containing occasional thin beds or discontinuous flakes of limestone; the "Green Shales" of Minnesota geologists.	12
5.	Thin-bedded, bluish, rather coarse-grained limestone, weathering brownish in color	5
4.	Limestone, in rather heavy layers which range up to fifteen inches in thickness; bluish on fresh fracture, but weathering to buff on exposure	5
3.	Brittle, fine-grained, blue limestone, very fossiliferous, breaking up on weathered surfaces into flexuous layers about two inches in thickness	20
2.	Lower buff beds, exposed, about	8
1.	Unexposed to level of water in river	45

The "Green Shale" No. 6, of the above section, and the limestones above and below were sampled and analyzed by Mr. Lundteigen with the results given below:

Analyses of Trenton Limestone.

	I	II	III	IV	V	VI
Silica, SiO_2	7.28	2.25	46.34	8.98	5.00	54.90
Alumina and **Iron oxides** $\left\{ \begin{matrix} Al_2O_3 \\ Fe_2O_3 \end{matrix} \right\}$	1.27	1.32	19.90	2.58	2.07	25.50
Lime, CaO	46.93	49.66	10.27	41.32	50.22	.41
Magnesia, MgO	2.58	3.24	2.13	5.80	.85	.30
Alkalies by difference	....	....	....	....	.76	9.55
Sulphur, S	.39	....	.01	.00	.85	.24
Loss on ignition $\left\{ \begin{matrix} H_2O \\ CO_2 \end{matrix} \right\}$	40.10	42.80	13.90	40.00	40.25	9.10
	99.25	99.27	92.55	98.68	100.00	100.00

I. Beds 8 and 9, Specht Ferry Section.
II. Bed No. 6, Specht Ferry Section.
III. Bed No. 5, Specht Ferry Section.
IV. Bed No. 4, Specht Ferry Section.
V. General sample of limestone, Specht Ferry Section.
VI. General sample of clay, Specht Ferry Section.

While the amount of magnesia in certain of these beds is higher than is desirable, there is still a large amount of rock available which is not higher in that element than that elsewhere used. It is probable that careful search would locate even better beds at the same horizon farther north.

DEVONIAN LIMESTONES.

There are in Iowa beds representative of both Upper and Middle Devonian. The former includes the State Quarry beds in Johnson county*, and the Sweetland shales in Muscatine†. The larger portion of the Iowa section belongs to the Middle Devonian, which may be divided into three formations, the Lime Creek, Cedar Valley and Wapsipinicon. In various counties these formations have been subdivided and individual members have been mapped. The Lime Creek and Wapsipinicon formations each include some shale and magnesian rock, but in general the Devonian limestones in Iowa are characteristically free from magnesia.

Wapsipinicon formation.—This formation was first discriminated by W. H. Norton who has discussed it in considerable

* Calvin, S., Geology of Johnson County, Iowa Geol. Surv., Vol. VII, pp. 33-104.
†Udden, J. A., Geology of Muscatine County, Iowa Geol. Surv. Vol. IX, pp. 247-388.

[illegible] and has mapped various subdivisions belonging to it in [illegible] Cedar[illegible] and Scott‡ counties. J. A. Udden has dis-[illegible] it in Muscatine county§, and Calvin has mapped [illegible] members belonging to it in Johnson and Buchanan.¶ [illegible] the development of the formation may be learned [illegible] reports cited. In the northern portion of the state [illegible] overlap, so that the Wapsipinicon is not repre-[illegible] general it may be stated that while the formation [illegible] and some very pure limestones, the mag-[illegible] abundant in almost any section and [illegible] be necessary to determine the availa-[illegible] given point. The Fayette breccia. [illegible] of the Wapsipinicon includes, near [illegible] is shown by the following

[illegible]

Lime Creek shales intervene between the latter and the Cedar Valley.

In the southern portion of the area of outcrop the Cedar Valley Limestone is characteristically a non-magnesian limestone, usually fine-grained in texture and breaks with a sharp conchoidal fracture. This phase of the formation is excellently exposed in Johnson county, and the following analysis was made by George Steiger, in the laboratory of the U. S. Geological Survey, from an average sample representing the rock quarried at Iowa City. These quarries exposed a total thickness of about fifty feet.

Analysis Devonian Limestone at Iowa City.

SiO_2	3.08
Al_2O_3	1.24*
Fe_2O_3	.73
CaO	50.30
MgO	2.22
SO_3	.06

Toward the north the limestone becomes more magnesian until in Howard county it is a massive dolomite which has been mistaken for the Niagara. About midway the rock has been extensively quarried at Independence and Waterloo where it is a soft, easily crushed limestone, apparently non-magnesian in character. At Waverly the rock is soft, thin-bedded and exposed to a total thickness of about fifty feet. Analysis of two separate beds, by Lundteigen, gave the following results:

Analyses of Devonian Limestone at Waverly.

	I	II
SiO_2	46.34	2.25
Al_2O_3, Fe_2O_3	19.90	1.32
CaO	10.27	49.66
MgO	2.00	3.24
SO_3	.01	.00
Loss on ignition	13.90	42.80
Total	92 42	99.27

* With the Al_2O_3 is included any TiO_2 or P_2O_5 present.

Still farther north, in Mitchell county, the limestone has attracted attention because of certain beds being lithographic.* The following analysis, made by Mr. A. B. Hoen, suggests that some, at least, of the stone is sufficiently free from magnesia to be suitable for cement material.

Analysis Devonian Limestone, Mitchell County.

SiO_2	.78
Al_2O_3	.12
CaO	54.91
MgO	.07
Na_2O	.18
K_2O	.11
CO_2	43.16
H_2O	.35

There are a number of fine exposures showing a thickness of ten to fifteen feet of the non-magnesian stone. Not all of it is free from cracks and crystals as is the lithographic layer, but it is similar in composition to the sample analyzed at the Gable and other quarries, there is practically no stripping, while in the vicinity is an abundance of loess clay.

Lime Creek Shales.—The uppermost member of the Devonian section of Iowa is well displayed in Cerro Gordo county, and has been discussed and mapped in Calvin's report on that area.†

He gives the following general section of the formations.

General Section of the Lime Creek Shales.

		FEET.
6.	Calcareous beds, light gray in color	20
5.	Magnesian shales and argillaceous dolomites	30
4.	Limestone with slender Idiostroma	4
3.	Fossiliferous, calcareous shales	20
2.	Yellow, non-fossiliferous shales	10
1.	Blue, non-fossiliferous shales	40

Nos. 1, 2 and 3 of this section make up the Hackberry member of the formation, while the remaining beds represent the Owen beds. The shales constituting the lower portion of this section are now in use at Mason City for the manufacture of

*Iowa Geol. Surv., Vol. XIII, pp. 292-352.

†Geology of Cerro Gordo County, Iowa Geol. Surv., Vol. VII, pp. 117-192.

clay goods, and are represented in the following analysis made by G. E. Patrick:

Analysis of Lime Creek Clay at Mason City.

	FEET.
Silica SiO_2	54.64
Alumina Al_2O_3	14.62
Iron oxide (calculated as Fe_2O_3)	5.69
Manganese oxide (calculated as MnO)	.76
Lime CaO	5.16
Magnesia MgO	2.90
Soda Na_2O	1.12
Potash K_2O	4.77
Carbonic acid CO_2	4.80
Hygroscopic water (expelled at 100° C.)	.85
Combined water (expelled by ignition)	3.74
Total	99.05

This analysis represents only the non-calcareous portion. The beds above contain considerable lime as noted in the section given. In the vicinity of Mason City where these beds outcrop there are extensive exposures of the non-magnesian beds of the underlying Cedar Valley, and it should be possible to combine the two to advantage.

CARBONIFEROUS LIMESTONES.

Carboniferous rocks underlie a large portion of Iowa. They include limestones, sandstones, shales and coals. The limestones are very rarely magnesian and because of this fact, as well as their excellent situation with reference to fuel and transportation facilities, it seems not improbable that time will see the development of a considerable cement industry based upon them. Of the three series into which the Carboniferous has been divided, two, the Mississippian and the Pennsylvanian are represented in this state. The Mississippian may be divided into the Kinderhook, Augusta and Saint Louis, each containing important limestone beds. The Pennsylvanian includes the Des Moines formation (lower Coal Measures) and the Missourian (upper Coal Measures). The lower Coal Measures includes most of the coal beds worked in the state, but very little limestone. The formation outcrops in a broad belt

between the limestones of the Mississippian series to the east and the calcareous shales and thin limestones of the Missourian formation. The general distribution of the Mississippian, Des Moines and Missourian beds is shown on the geological map of Iowa. The details as to character, thickness, etc., in any area may be learned from the appropriate county reports*.

Kinderhook limestone.—The Kinderhook forms the lowermost division of the Carboniferous of this state. It consists for the most part of a soft argillaceous shale which is exposed to a thickness of sixty feet at Burlington.† Above the shale are about fifty feet of sandstone and limestone belonging also to the Kinderhook. In general the beds are not well exposed, and in the southern area of outcrop are not likely to be of importance in cement manufacture, except as a source of clay to be mixed with the overlying Burlington limestones. Farther north, in Marshall county, there is an extensive development of limestone. The rock is quarried at Le Grande, and the following analyses by G. E. Patrick indicate that a considerable portion of the stone is suitable for cement manufacture:

*Reports upon counties in which the Carboniferous rocks are important will be found in the volumes of the Iowa Geological Survey as follows:

Appanoose, V, 861-488;
Boone, V, 175-240;
Dallas, VIII, 51-118;
Decatur, VIII, 255-888;
Des Moines, III, 409-492;
Fremont and Mills, XIII, 128-188;
Guthrie, VII, 418-488;
Hardin, X, 241-814;
Henry, XII, 287-802;
Humboldt, IX, 109-154;
Jefferson, XII, 855-488;
Keokuk, IV, 255-812;
Lee, III, 805-408;
Louisa, XI, 55-126;
Madison, VII, 489-540;
Mahaska, IV, 818-880;
Marion, XI, 127-198;
Marshall, VII, 197-262;
Mills and Fremont, XIII, 128-188;
Monroe, XIII, 858-438;
Montgomery, IV, 881-452;
Page, XI, 897-460;
Polk, VII, 268-412;
Pottawattamie, XI, 199-278;
Story, IX, 155-246;
Van Buren, IV, 197-254;
Wapello, XII, 489-499;
Warren, V, 801-860;
Washington, V, 118-174;
Webster, XII, 62-191.

†Weller, Stuart, Iowa Geol. Surv.. Vol. X, p. 65.

Chemical Analyses of Le Grande Stone.

	I	II	III	IV
Silica and insol	.77	.96	1.24	1.22
Alumina Al_2O_3	.05	.07	.18	.14
Iron Fe_2O_3	....	....	.15	.26
Iron FeO	.09	.27	.09	.09
Manganese oxide (as MnO)	....	08	....	trace
Lime CaO	55.05	54.85	50.56	50.42
Magnesia MgO	.28	.28	3.70	3.96
Carbonic acid CO_2	43.62	43.30	43.79	43.85
Hygroscopic water (loss at 100° C.)	.03	.09	.06	.04
Combined water (expelled by ignition)	.13	.21	.15	.12
Phosphoric acid	....	....	trace	....
Total	100.02	100 11	99.92	100.10

Probable Combinations.

Silica and silicates, iron, alumina, oxides, etc.	.95	1.37	1.74	1.72
Calcium carbonate	98.30	97.95	90.28	90.04
Magnesium carbonate	.59	.38	7.77	8.08
Water	.16	.30	.21	.16
Total	100.00	100.00	100.00	100.00

I. Fine-grained öolite.
II. Blue limestone.
III. Iowa Caen stones.
IV. Stratified limestone.

Associated with these beds are certain others which are more magnesian, but which happen to be in demand as building stone. Possibly a combination of industries could be based on this association. In Hardin county there is a considerable thickness of the rocks with some associated shale. Still farther to the north and west the Kinderhook outcrops, but without exposing any great thickness. While much of the Kinderhook limestone is magnesian, it is believed that in localities where other conditions are favorable, the formation warrants prospecting and testing.

Augusta formation.—The Augusta includes beds which have been widely known as the Keokuk and Burlington limestones together with a portion of the Warsaw. The formation consists for the most part of coarse, crinoidal limestone, white, non-magnesian, and with chert in nodules along bedding planes.

8

The limestone is associated with abundant argillaceous shale. and often outcrops in steep bluffs, at the foot of which the shales of the Kinderhook are available. The beds are best exposed in Lee and Des Moines counties, but occupy portions of Louisa, Washington, Henry and other counties in the southeast part of the state.

At Burlington, in the south bank of the Cascade Hollow the following section was measured by Mr. T. E. Savage:

Cascade Hollow Section.

		FEET.
7.	Fine-grained, homogeneous soil material without pebbles, dark-colored above grading down to yellow below	4
6.	Clay with pebbles and small bowlders of granite and greenstone, reddish-brown	6
5.	Limestone, much decayed, in layers one to four inches thick, numerous chert nodules	5
4.	Chert	⅔
3.	Limestone, crinoidal, coarse-grained, layers four to eight inches thick	4
2.	Limestone, crinoidal, with chert nodules	1
1.	Limestone, coarse, crinoidal; at places massive, at others weathering into layers three inches to one foot in thickness, containing numerous fossils	10

An average sample of this limestone was analyzed by George Steiger in the laboratory of the U. S. Geological Survey with the following results.

Analysis Burlington Limestone.

SiO_2	5.18
*Al_2O_3, Fe_2O_3	.87
CaO	52.16
MgO	.40
SO_3	.00

The beds outcropping at this point are thoroughly representative of the Burlington limestone, the most important division of this formation. Greater thicknesses are exposed at other points and the total thickness has been estimated to be about two hundred and fifty feet.

* This figure includes any TiO_2 or P_2O_5 present.

St. Louis Limestone.—The St. Louis is one of the most widely distributed formations in Iowa. It rests on the Augusta and lies unconformably below the Des Moines formation. On account of its relation to the coal beds it has been carefully mapped and extensively studied. It includes three minor divisions, the Pella beds, the Verdi beds and the Springvale beds. Of these the first named is much the most important from the present point of view. The Verdi and Springvale beds have limited areas of outcrop and are usually not suitable in composition for cement manufacture. The Pella beds on the other hand outcrop widely and are, in composition, excellently adapted to this purpose. They fringe the productive coal measures on the east and occur as scattered inliers within the general area of outcrop of the coal beds. This results from the pronounced unconformity between the Des Moines and the St. Louis, hills of the limestone rising like islands above the lowest coal beds.

The Pella beds usually show an upper portion consisting of calcareous marl with some thin beds of limestone. This facies is ordinarily eight to ten feet thick. Below it are beds of fine-grained, blue to gray limestone breaking with clean conchoidal fracture and usually thin-bedded. The rock is very rarely magnesian and the analysis quoted below is quite representative. The sample was taken from the Chiiton quarry at Ottumwa, by Mr. T. E. Savage. The beds exposed at this quarry are noted in the following section:

Chilton Quarry Section.

		FEET.
13.	Fine-grained, dark colored, pebbleless soil....	1
12.	Clay, reddish-brown, with pebbles	3
11.	Sandstone, brown, iron-stained, mostly incoherent, but in places indurated (Des Moines)	10
10.	Calcareous shale, weathering into small bits, very fossiliferous..........................	3
9.	Limestone, dense, fine-grained, gray..........	2½
8.	Limestone, shaly, soft, weathering readily, similar to No. 10..........................	2
7.	Limestone, dense, fine-grained, gray..........	1½
6.	Shale, calcareous..............................	3
5.	Limestone, hard, fine-grained, gray, fossiliferous....................................	1

		FEET.
4.	Limestone, dense, bluish	1
3.	Limestone, dense, fine-grained, bluish-gray, in part massive, in part thin-bedded, fossiliferous	4
2.	Limestone, hard, gray	1¼
1.	Limestone, dense, gray	1½

An average sample of the limestone and marl here was analyzed in the laboratory of the U. S. Geological Survey, by George Steiger, with the following results.

Analysis of St. Louis Limestone at Ottumwa.

SiO_2	6.83
Al_2O_3	2.12*
Fe_2O_3	.54
CaO.	49.54
MgO	.07
SO_3	.13

Samples of limestone from Pella, Tracey, Oskaloosa and Humboldt have also been analyzed with the following results:

	I	II	III	IV
SiO_2	4.92			
Insol		1.57	4.01	.91
Al_2O_3	3.39 (with Fe_2O_3)	.49	.13	.48
Fe_2O_3		.17	.46	.73
CaO	47.50			
$CaCO_3$		94.60	95.30	97.98
MgO	.00	3.17	.00	
Alkalies				
SO_3	2.09			
CO_2	38.10 (with H_2O)			
H_2O				

I. Limestone, Pella, Lundteigen, Anal.
II. Limestone, Tracey, Murray, Anal.
III. Limestone, Oskaloosa, Murray, Anal.
IV. Limestone, Humboldt, Murray, Anal.

*This figure includes any TiO_2 or P_2O_5 present.

Analyses of limestone and interbedded shale from the mouth of Lizard creek in Webster county, were made by Mr. Lundteigen, with the following results:

		$CaCO_3$	$CaSO_4$
3.	Upper, limestone, 2 feet	88.75	.28
2.	Middle, shale, 2 feet	53.25	2.46
1.	Bottom, limestone, 2½ feet	88.75	.17

A cement made from this material gave the following analysis and on test showed satisfactory color, strength and setting properties:

Analysis Fort Dodge Cement.

Silica	25.52
Alumina and iron	8.80
Lime	63.40
Magnesia	1.19

The material from the Pella exposures has been made up into a cement which has good color, is sound on glass, sets very quickly and has satisfactory strength. The results of these tests, together with the fact that limestone of the same age and character is being extensively used at St. Louis, Missouri, makes it certain that this formation can be relied upon to furnish the calcareous element wherever other conditions are favorable to the establishment of cement plants.

Des Moines formation.—The Des Moines (lower Coal Measures) contains very little limestone. Its principal importance in the present connection arises from the coal and clay which make up so large a portion of the formation. The clays and shales are extensively used in the brick making industry. They are available over wide areas and may prove of service in connection with limestones of the formations above and below. The following analyses are typical of these clays:

Analyses of Coal Measures Shales and Clays.

	I	II	III
SiO_2	53.08	64.41	53.86
Al_2O_3	17.71	20.43	26.28
Fe_2O_3	8.64	5.88	4.32
CaO	4.05	.34	.12
MgO	.94	1.71	.43
Na_2O	3.70	1.90 (Na₂O and K₂O together)	.43
K_2O	1.25		2.52
SO_3	....	....	1.22
CO_2	2.53	....	....
H_2O (combined)	6.77	3.93	3.02
H_2O (free)	....	1.27	....
Undter. and ignition	1.33	....	8.06

I. Brick clay, Fort Dodge.

II. Brick clay, Des Moines, C. O. Bates, Analyst.

III. Brick clay, Ottumwa, J. B. Weems, Analyst.

Near the middle of the Des Moines formation there are a series of strata which have been called the Appanoose beds. These have been mapped and discussed in connection with the report on Appanoose county, and the outcrop of the "Fifty-foot" limestone, one of their important members, is shown on the accompanying map. The Appanoose beds include the Mystic or Centerville coal and certain associated shales and limestones. The latter are known locally, from their relations to the coal, as the "Bottom rock," "Cap rock," "Thirteen-foot limestone," and "Fifty-foot limestone." The beds are thin, usually from four to six feet in thickness, but near Rathbun and Clarkdale the Fifty-foot rock reaches a thickness of ten to fifteen feet. It is a soft limestone, easily crushed, and because of its close association with clay and a very good coal bed, is probably of value. Analyses show that it is practically free from magnesia and runs from 74 to 93 per cent in calcium carbonate. The following analysis by Lundteigen is representative:

Analysis Fifty-foot rock, Rathbun.

SiO_2	9.90
Al_2O_3, Fe_2O_3	6.40
MgO	trace
$CaCO_3$	83.37

Missourian formation.—The southwestern portion of Iowa is underlain by the rocks of the Missourian formation or upper Coal Measures. In contrast with the lower Coal Measures or Des Moines formation, the Missourian includes considerably less sandstone and very little coal. The beds are mainly shales and limestones. The latter are almost entirely free from magnesia, are occasionally somewhat earthy and are usually free from chert, and easily ground. They are accordingly well adapted to cement manufacture and indeed the equivalent beds are now in use at Iola, Kansas. The individual members of the Missourian formation have not been mapped in Iowa, though they are discussed in the county reports. The most important limestone lies at the base of the formation and its outcrop is accordingly indicated on the geological map by the eastern edge of the formation. This limestone, which is variously known as the Winterset, Earlham and Bethany, is discussed in some detail in the Madison county report.

The Bethany limestone in Madison county includes four separate ledges occurring in the following order and thickness: Fusulina, twenty-five feet; Winterset, twenty feet; Earlham, twenty-one feet; Fragmental, ten feet. These ledges are separated by shale beds, usually ten to twenty feet in thickness, and in part calcareous. The rocks are quarried at various points, particularly Earlham, Winterset and Peru, and the same ledges have been recognized as far south as Decatur county on the Missouri boundary.

Analyses of individual ledges at Peru, made by Lundteigen, show a lime content ranging from 60.50 per cent to 83 per cent. A cement mixture made from them gave 75.50 per cent $CaCO_3$. At Earlham the following section was measured by Mr. T. E. Savage, and an analysis of an mixed average sample of the stone was made in the laboratory of the U. S. Geological Survey by George Steiger. The results are given below:

Section of Robertson Quarry, Earlham.

		FEET.	IN.
19.	Dark colored, fine-grained, pebbleless soil.	1	
18.	Reddish bowlder clay with pebbles and quartzite fragments	1	6
17.	Yellowish colored, soft, shaly limestone which disintegrates readily	4	
16.	Layer of very hard, light gray, fine-grained limestone		7
15.	Narrow layer of softer limestone with less perfectly comminuted fossil fragments		2
14.	Ledge of hard, white limestone, fine-grained, separating in places into three or four uneven layers	3	
13.	Soft, calcareous shale which weathers rapidly into fine bits		4
12.	Dense, gray limestone, fine-grained, fossil fragments abundant but indistinct		6
11.	Gray shale like No. 9		1½
10.	Layer of hard, gray limestone		2
9.	Band of soft shale		1½
8.	Dense, fine-grained, light gray limestone, in places massive, again separating into two layers of about equal thickness	1	8
7.	Shale, soft, gray in color, and quite calcareous		6
6.	Layer of impure limestone, grayish-yellow in color		2½
5.	Band of soft, gray, calcareous shale		7
4.	Ledge of hard, fine-grained, light colored limestone, imperfectly separated into three uneven layers	1	3
3.	Massive layer, separating in places into two uneven layers with shaly partings between them, and such partings of shale separating No. 3 from No. 4 above and from No. 2 below	1	4
2.	Ledge of gray limestone	1	3
1.	Layer of gray limestone	1	8

Analysis Earlham Limestone.

SiO_2	10.92
Al_2O_3	1.77*
Fe_2O_3	.60
CaO	47.66
MgO	.75
SO_3	None.

* This includes any P_2O_5 or TiO_2 present.

The beds above the Bethany have not been as carefully studied though they are apparently similar in composition and character. The next higher limestone, the DeKalb, yielded the following on partial analysis by J. B. Weems:

Analysis DeKalb Limestone.

$CaCO_3$	91.96
$MgCO_3$	1.99
H_2O	.07

SUMMARY.

It is believed that the data presented bear out the assertion that there are many points in Iowa at which materials suitable for cement manufacture are available. The marls are not now known to be important and may never prove to be. Chalk suitable in all particulars may be found along the Sioux river north of Sioux City. As this is a soft, easy grinding material, it is a favorite among cement manufacturers. The question of the advisability of establishing a plant in this district must be determined by consideration of manufacturing costs, of market and transportation facilities.

In regard to the limestones the following general considerations are important. Iowa is largely a drift covered state and within the broad areas shown upon the map as underlain by the various limestones there are really only a limited number of outcrops. Even where outcrops occur, the overburden is in many cases so thick as to entail prohibitive stripping costs. The best situations are in the valleys, usually where some important tributary joins the main stream. Fortunately, many of the railway lines follow valley routes.

The Trenton limestone, which occurs in the Driftless Area, is found usually in rather steep bluffs; a fact due to the resistant character of the dolomite usually found above it. As compared with the other limestones of the region the Trenton is more likely to carry magnesia in excess, but it is, on the other hand, practically free from chert, is often somewhat earthy in composition, and is intimately associated with shale. As already noted, the similar and approximately equivalent beds in the Lehigh district of Pennsylvania and New Jersey are a very important source of cement material.

The Devonian limestones are in large measure free from both chert and magnesia, though outcrops in the northern part of the state need careful examination to make sure of the absence of the latter. As contrasted with both the Trenton and the Carboniferous limestones they are in the main harder, and this will to some extent influence the cost of grinding.

Of the Carboniferous limestones the Kinderhook are in most situations too magnesian and the Augusta too full of chert for easy use, though it is probable that some suitable material can be found in each formation. The Pella beds of the St. Louis, and the Winterset and other limestones of the Missourian are entirely suitable as regards composition, freedom from chert and grinding qualities. Equivalent beds are now in use in Missouri and Kansas. These limestones are, furthermore, excellently situated as regards fuel and clay. The productive Coal Measures (Des Moines formation) outcrop in a broad belt between the two and often Pella beds and shales of the Des Moines occur in the same section. Where the shales are absent, loess, such as is elsewhere used, is nearly everywhere present.

RELATIONS TO FUEL AND MARKETS.

The area of the productive Coal Measures, Des Moines formation, is shown on the geological map of Iowa. It will be seen that the coal mines are so situated as to afford cheap fuel to most of the limestone localities. This is quite important since the fuel cost forms approximately 30 per cent of the total manufacturing cost. Iowa coal, while not of the highest grade, is still well adapted to cement manufacture. The following analyses indicate the approximate composition of a few of the coal beds. These analyses and tests were made at the Iowa State College of Agriculture, and are published in the report on Monroe county.*

Analyses of Iowa Coals.

	Volatile Combustible.	Fixed Combustible.	Total Combustible.	Ash.	Sulphur.	B. T. U.
Average five Monroe county coals...	42.32	46.81	89.13	10.13	4.10	11,922
Centerville Block Coal Co., Appanoose county....................	37.79	54.85	92.64	7.36	3.29	12,681
Corey Coal Co., Webster county.....	37.98	47.98	85.96	14.04	5.90	12,431
Des Moines C. & M. Co., Polk county.	45.62	50.29	95.91	4.09	2.74	12,041
Whitebreast Fuel Co., Pekay, Mahaska county..................	46.06	46.89	92.95	7.05	2.81	13,050
Carbon Coal Co., Willard, Wapello county..........................	36 94	54.20	91.14	8.86	2.86	12,245
Average 22 Illinois coals............	35.11	51.91	87.02	12.77	3.02	......
Pocahontas coal, Virginia...........	18.23	75 08	93.31	6.69	.60	......

In the above tables the Pocahontas coal is quoted for comparison, and the Illinois coals are noted since, in event of the Trenton limestone being used, coal would probably be drawn from Illinois rather than Iowa. Many additional analyses will be found in the special report on the coal deposits forming volume II of the reports of the Iowa Geological Survey, and some additional data in the Twenty-second Annual Report of the U. S. Geological Survey.*

In the majority of the newer cement plants of the United States, powdered coal is used as a fuel. The Iowa coals are well adapted to this method of firing. The methods of burning cement and the cost of fuel have already been discussed.

The relations to transportation lines are perhaps clearly enough indicated by the map. It is sufficient to notice that there are several promising localities along the Mississippi river where the latter could be utilized directly and would in addition act as a regulator of railway rates. The main railway lines of Iowa run either east-west or southeast-northwest and much of the freight originating in the state, aside from agricultural products, moves to the north and west. Any cement plant which may be established would find a ready market in the same direction. Iowa, itself, affords a very considerable market for

*The Western Interior Coal Field, Twenty-second Ann. Rept., U. S. Geol. Surv., pt. iii, pp. 333-366.

cement, and an Iowa cement plant would have considerable advantage in reaching an important and growing market to the north and west.

Despite the large amount of material available, and the convenient fuel and transportation facilities, no Portland cement plants have been established in Iowa. In neighboring states a number are in operation and others are building or in contemplation.

CEMENT PLANTS IN NEIGHBORING STATES.

One of the oldest plants in the middle west is located at Yankton, S. D., were the Western Portland Cement Company makes use of the chalk and clay found in the Cretaceous. In Illinois there are three large and well equipped plants near LaSalle, using a Coal Measure limestone similar to the "Fifty-foot" rock, outcropping in Appanoose county, in connection with ordinary Coal Measure shale. There is also a Portland cement plant in Chicago, in connection with the works of the Illinois Steel Company. In Missouri there are three plants. At Saint Louis, loess, Coal Measure shale and Saint Louis limestone are used. At Louisiana the Louisiana limestone will be used in a new plant now being erected. At Hannibal the Atlas Portland Cement Company has a large plant running on the Burlington limestone and Kinderhook shales. In Kansas there are two plants at Iola, one of which is very large, which manufacture an excellent grade of cement from beds equivalent to those occurring in the Missourian formation as mapped in Iowa. These plants have heretofore had the advantage of a cheap fuel in the natural gas of that field. As the gas pressure is steadily decreasing they will, doubtless, eventually, be compelled to use coal for fuel.

In addition to these plants, there are natural cement plants at Mankato and Austin, Minnesota, at Milwaukee, Wisconsin, Utica, Illinois and Fort Scott, Kansas. To the north and west the possible trade territory is thus practically unoccupied. In North Dakota there is a small plant devoted to the manufacture of natural cement, and in Colorado and Utah there is one Portland cement plant each. In view of these favorable trade conditions it would seem that one or more Iowa plants might confidently be expected to prove successful.

GEOLOGY OF BENTON COUNTY.

BY

T. E. SAVAGE

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Benton county is located in the east-central portion of Iowa. It lies across the middle line of the state from north to south while its eastern border is about seventy-two miles from the Mississippi river. It is a rectangle in form, thirty miles in length in a north and south direction, twenty-four miles in width, and embraces an area of 720 square miles. The extreme southwestern portion of the county is cut by the channel of the Iowa river, and the northern part is crossed diagonally by the valley of the Cedar.

Benton is bordered on the north by the counties of Black Hawk and Buchanan, on the east by Linn, Iowa county touches it on the south, and Tama joins it on the west. Of these areas Buchanan county has been described by Professor Calvin in a previous volume of the Iowa Survey reports. Linn county has been discussed by Professor Norton, and Tama has been investigated by the present writer. The county includes twenty congressional townships—townships 82-86 north and ranges IX-XII west. It is divided into twenty civil townships, fifteen of which are of the usual size while the other five—Cedar, Harrison, Polk, Taylor and Benton—which are located towards the the northeast corner, are more or less irregular in size and form owing to the fact that their boundaries are in part determined by the winding channel of the Cedar river.

Benton is pre-eminently an agricultural county. It is situated in the midst of the finest agricultural portion of our peerless state. The larger part of this beautiful area lies within the region covered by the Iowan ice sheet, and the drift of this age furnishes to the county a soil that is unsurpassed in depth, fertility and productiveness. Well tilled farms of ample size; beautiful homes with attractive surroundings; numerous farm buildings, large and commodious; these are the evidences which lend a substantial air of thrift and prosperity to the inhabitants of this fortunate region.

EARLIER GEOLOGICAL WORK.

Benton county lies outside of the main area of the Coal Measures of Iowa, and consequently the history of the early exploitations of that mineral did not involve this particular portion of the state. No valuable mineral deposits of any kind and no large areas over which the indurated rocks are exposed attracted the practical students of geology to this region. The problems of the superficial deposits did not appeal to workers in the science of geology until recent years, hence the chroniclers of early explorations in Iowa rarely give to our county even passing notice.

The pioneer geologist *Dr. D. D. Owen does not mention the county by name but he might well have referred to her billowy surface when he thus described the rural beauty of a portion of the state: "Undulating prairies interspersed with open groves of timber and watered with pebbly or rocky-bedded streams, pure and transparent; hills of moderate height and gentle slope; here and there, especially toward the heads of the streams, small lakes as clear as the rivers, some skirted with timber and some with banks formed by the green sward of the open prairies; these are the ordinary features of the pastoral landscape."

In Hall's† Geology of Iowa, published in 1858, Professor Whitney speaks of an exposure of limestone of Hamilton age near the town of Shellsburg. He also mentions a few places near Vinton where outcrops of the rocks of the same age occur.

In another place Mr. Whitney‡ discusses the probability of local beds of Carboniferous strata underlying the superficial materials of the area under consideration.

In the report on Iowa Geology by Dr. C. A. White not a word is said with respect either to soils or topography, or to the indurated rocks or the Pleistocene deposits that occur within the borders of Benton county.

W J McGee,§ in his Pleistocene History of Northeastern Iowa, refers in a general way to the drainage, and the behavior

*D. D. Owen: Report Geol. Sur., Wisconsin, Iowa and Minnesota, p. 100, 1852.
†Hall and Whitney: Geology of Iowa, Vol. I, Pt. 1, pp. 262 and 268. 1858.
‡*Ibid*, p. 264.
§McGee: Eleventh Ann. Rept. U. S. Geol. Surv. p. 221 *et seq*. 1891.

of some of the streams. He also mentions deposits of loess and sand that occur at various points within the area, and gives a few sections of wells put down in this particular region.

In discussing the Paleozoic strata of Northeastern Iowa Prof. W. H. Norton* describes sections which show the different formations that were penetrated in putting down two deep wells in the town of Vinton. Again, in his report on the Artesian Wells of Iowa, Mr. Norton makes a detailed description of these wells and gives an analysis of their water.† In the latter report Professor Norton also discusses the Jumbo well at Belle Plaine.‡

Professor Chamberlain has published an account of the well at Belle Plaine which for a time after it was drilled provoked an unusual amount of discussion.§ A few years later Mr. Call described the Belle Plaine artesian well and attempted to explain the source of the water.‖ In 1898 Mr. Roy Mosnat presented an excellent account of the Artesian wells of the Belle Plaine area in the present series of the Iowa Survey reports.¶ This area includes the southwest portion of Benton county together with the southeast corner of Tama, a small area in the northwest corner of Iowa county and the northeast corner of the county of Poweshiek.

PHYSIOGRAPHY.

TOPOGRAPHY.

General description.—Over the greater portion of Benton county the topography is what physiographers designate as a prairie plain. The indurated rocks that underlie the superficial materials are of Devonian age, and have practically a horizontal position. There are no very great differences in altitude between the valleys and uplands, nor in general is there any great diversion from the gently undulating character of the prevailing landscape.

*Norton: Iowa Geol. Surv., Vol. III, pp. 192-195. 1893.
†Norton: Iowa Geol. Surv., Vol. VI, pp. 266-267. 1896.
‡Norton: Iowa Geol. Surv., Vol. VI, pp. 350-352. 1896.
§Chamberlain: The Artesian Well at Belle Plaine, Iowa, Science Vol. VIII, p. 276.
‖Call: Iowa Artesian Wells. Weather and crop service, Vol. III, March, 1892.
¶Mosnat: Iowa Geol. Surv., Vol. IX, pp. 523-526. 1898.

The county as a whole, however, embraces topographic phenomena of exceeding interest for the reason that the surface features over one portion of the area have been developed through the destructive processes of erosion, while those over another part of the region have been moulded by the constructive agency of ice.

The entire surface of the county is drift covered with the exception of small areas of fluvial deposits along the flood plains of the larger streams. The drift of the county has been derived from two different ice sheets, which, in time, are separated by an exceedingly long interval. The two topographic areas mentioned above are coincident with the areas over which the drift of these respective ice sheets are spread out at the surface. The older portion of the region, that over which the uppermost till is of Kansan age, embraces a little more than the south half of Iowa township, the south part of Leroy and a small area near the south side of the township of Saint Clair.

The history of this ancient surface is one of long continued exposure to the processes of weathering and the agents of erosion. It is recorded in the chemical and physical changes that have been accomplished in the superficial portion of the drift. It is revealed in the deeply carved and thoroughly dissected divides. It is reflected in the depth of the stream channels and in the great width of their flood plains. In general it is depicted in every feature of the landscape, which is typical of a water sculptured region approaching the conditions of topographic maturity.

The area over which the later or Iowan drift was spread embraces the most of the county with the exception of the older portion outlined above. That the topography of this area was impressed upon it by the ice is shown by the gentle curves and slight inequalities in the surface; by the scant development of definite stream channels and the absence of any widely extending series of secondary branches; by the presence of innumerable swales or saucer-like depressions which lie between low, rounded elevations, and which have not yet been obliterated either by filling or by drainage or by both of these means combined. The above are glacial phenomena and

they clearly testify to the recent retreat of the ice mantle and to the extreme topographic youthfulness of this portion of the county.

The Iowan-Kansan border.—The sinuous line of irregular elevations that marks the southern limit of the extension of Iowan ice in Benton county begins, on the west side, at the town of Belle Plaine. To the west and south of this place there is evidence that a tongue of Iowan ice pushed down the broad valley of Salt creek and for some distance overspread the flood plain of the Iowa river. To the north of Belle Plaine, for a distance of two miles, the line of hills passes near the west side of sections 17 and 8 of Iowa township. Not far from the northwest corner of section 8 it bends to the eastward for one-half mile across the north side of this same section. It then bends southward along the west side of section 9, forming for some distance the conspicuous bluffs in the west bank of Stein creek. In the northwest part of section 16, this line again bends eastward and continues in a sinuous manner not far from the north side of sections 16 and 15, and on to nearly the middle of section 14. Bending southward it passes diagonally across the southeast quarter of section 14, the southwest corner of section 13 and down to near the center of section 24. Turning eastward for nearly one mile it crosses a little to the north of the middle of section 24 of Iowa township, and thence passes towards the northeast a short distance south of the town of Luzerne. It continues towards the northeast across the northwest corner of section 19 of Leroy township, and on to the northeast corner of 18. From this point it bends eastward for three-fourths of a mile and then continues in a general southeast direction across the northeast corner of section 17, the southwest corner of section 16, the north end of section 22, the southwest corner of section 23 and the northeast corner of section 26. See figure 1. Continuing in a direction a little south of east, about one mile south of the town of Blairstown, it passes diagonally across the middle of section 25 of Leroy township and enters the township of Saint Clair, a few rods north of the southwest corner of section 30. From this point it continues in a general southeast direction near the south

side of section 30, and diagonally across the north side of section 32. It passes eastward near the middle of section 33 and then crosses diagonally the south half of section 34. It crosses the Benton-Iowa county line a little east of the middle of the south side of section 35 of Saint Clair township. This line of moraine-like ridges continues in a southeasterly direction across the northeast corner of Iowa county where it forms a conspicuous border of hills overlooking the south side of section 36 of Saint Clair township and sections 31, 32, 33 and 34 of Florence. From section 35 its trend takes it so far south into Iowa

FIG. 1. Iowan-Kansan border near the middle of Leroy township. These elevations also form the south bank of the valley of Prairie creek.

county that it appears as an indistinct line almost on the horizon's rim; and from the south side of section 36 it has entirely disappeared from view, being obscured from sight by the presence of intervening swells. In the townships of Saint Clair and Leroy the Iowan border is beautifully preserved and is very conspicuous. As one approaches from the north, the line of hills rises abruptly to a height of fifty to seventy feet above the comparatively level Iowan plain. In Iowa township the margin is less distinct. The Iowan surface is here much

more broken; the pre-Iowan topography not having been greatly altered. For this reason the contrast between the surface of the Iowan plain and the line of hills that borders it is not so clearly marked in Iowa township as it is further east, in the townships of Leroy and Saint Clair. To the careful observer of land forms, however, the subdued and rounded character of the elevation, together with the choked condition of the stream channels over this portion of the Iowan area will be quite readily discriminated from the higher, and more deeply sand or loess covered hills with sharper contours and the more open waterways which are presented in the region of the Iowan-Kansan border in Benton county.

These elevations can scarcely be called a moraine as that term is usually understood, for they contain no proper unspread Iowan drift. In fact, the Iowan glacier deposited scarcely any pebbles or finely pulverized detritus over this portion of the region which it invaded. It would seem probable, also, that the ice became so exceedingly thin at its southern margin in Benton county that its onward flow was obstructed where the stronger hills were encountered, the ice continuing to advance further where the movement was over level areas of prairie or flood plain.

As an obstruction the hills may have acted in part in the nature of a barrier to the glacier's advance, and again their presence would be a cause of the much more rapid melting and destruction of the ice, owing to the partial breaking up of the attenuated mass as it moved over the very uneven surface. Thus it seems possible that the presence of such hills may have determined the particular line of lower limit reached by the Iowan glacier in this portion of the state. The hills immediately adjacent to the ice margin would receive the deepest deposits of loess or sand which was swept from the surface of the melting glacier by the agencies of wind and water. It is the presence of these deep deposits of loess or sand overlying the ancient hills of Kansan drift which increases to such an extent the altitude of the elevations along the Iowan border above that of the hills over the unmodified portion of the Kansan drift plain, and which makes the transition from the com-

paratively level surface of the Iowan plain to that of the Kansan so abrupt and conspicuous. That the presence of hills determined in some measure the particular line to which the southern margin of the Iowan ice advanced would seem probable from the fact that around the most of its southern border such a line of hills bounds the Iowan plain. Where the ice moved over a level area it advanced further southward, as is shown in the lobe which occupied the valley of Salt creek in the western portion of the county. The cores of the bordering hills are composed of till of Kansan age. In the upper portion of this drift, immediately beneath the covering of sand or loess, there is a zone in which the drift is thoroughly leached of its lime constituent and in which the contained iron is highly oxidized, coloring the till a dark reddish-brown to a depth of two to four feet, the transition being gradual down to the unchanged blue color of the drift below. Recent erosion has in numerous places exposed this leached and oxidized horizon which in all cases conforms to the present contour of the hills. These facts would indicate that the bordering hills were carved by erosion long before the invasion of the Iowan glacier or the deposition of the overlying mantle of loess or sand; that they were present at the time of advance and opposed the onward movement of the Iowan ice.

If they did determine in some measure the distance southward which the Iowan glacier attained, the ice near the margin must have been exceedingly attenuated for its flow to be influenced by such slight inequalities in the surface. If the Iowan ice movement was thus influenced near the margin by the presence of hills we have a possible explanation of why, within a few miles of its border, there are left paha-like hills and pre-Iowan island areas, both overlain by loess, such as appear near the towns of Garrison, Watkins and Norway, and which occur at other places along its southern margin; of why the Iowan border presents such a large number of narrow, digitating lobes, as at Salt creek and at numerous points to the east of Benton county; of why its margin in so many places coincides for some distance with one of the bordering banks of a pre-glacial stream as in the case of Deer creek and Salt creek

in Tama county, and Stein and Prairie creeks in the county of Benton; of why in other cases the Iowan ice seemed to avoid the immediate vicinity of the larger streams, and why it should follow parallel with, but at some distance from, the valley of the Iowa river through the counties of Benton and Iowa.

The Kansan area.—The portion of Benton county over which the superficial drift is of Kansan age has been outlined above. It embraces about forty square miles, twenty-five thousand six hundred acres, in the extreme south and southwest portion of the county. The northern border of this area follows a sinuous line that is approximately parallel with the channel of the Iowa river, and which has an average distance from that stream of about five miles.

As would be expected from its proximity to the river, the Kansan plain is here deeply gashed and trenched by an intricate system of stream channels so that no large undissected upland areas are left in this portion of the county. The wagon roads have in many places no relation to the section lines, but follow the channels of the streams, or wind in a zigzag manner along the tops of the narrow divides. From these ridges the traveler looks off on either side over an almost endless series of hills and ravines. The tops of the elevations rise sixty to eighty feet above the deeper valleys. The slopes are quite steep. The bottom of the smaller runnels are open and their sides are sharply angular, testifying to the activity of erosion at the present time. A comparatively mild type of Kansan drift topography is shown in figure 2.

As is usual throughout a belt some miles in width around the immediate margin of the Iowan plain, the Kansan surface is mostly covered by a heavy deposit of homogeneous, unconsolidated material which is usually composed of loess or occasionally of rather fine-grained, yellow colored sand. This material varies in depth from a few inches to fifteen or twenty feet. All of the area of Kansan drift in Benton county has been modified by the presence of this more recent deposit. At numerous points over the area, the streams have cut their channels through the covering of loess and revealed the presence of the underlying Kansan drift. Such exposures may

be seen along the roadway between sections 13 and 14, and again between sections 14 and 22 of Iowa township; also along the south part of section 34 of Leroy township and at very many other places over the area. These exposures reveal the fact that the loess forms a mantle over the old and deeply eroded Kansan surface duplicating more or less perfectly the configuration of the surface of this underlying drift.

The profound erosion which the region has suffered was practically accomplished during the long period that intervened between the withdrawal of the Kansan ice sheet and the deposition of the loess.

FIG. 2. Mild erosional topography of the Kansan drift area in section 26, Leroy township, one and one-half miles south of Blairstown.

The loess is not of a perfectly uniform depth over the summits and the slopes. Usually the thickness is somewhat greater near the crests of the hills but, as far as the topography is concerned, its presence serves only to enhance the abruptness of the curves, the steepness of the slopes and the height of the hills.

The larger streams of the region flow in valleys of pre-Kansan age. Their waters have swept from side to side in broad curves

and expanded their channels into wide flood plains. The Iowa river in Benton county has developed such a flood plain more than two miles in width. Stein creek flows in the midst of such a plain which is three-fourths to one mile broad, while the smaller streams follow valleys that are exceedingly wide in proportion to the volume of water which they carry.

The Iowan area.—The area in Benton county that was covered by the Iowan ice sheet includes the most of that portion lying to the north of the bordering line of hills traced above. It embraces very much the greater portion of the county. In this region the topography is that of an undulating prairie over which gentle swells and grassy swales alternate in almost endless succession.

Over the most of this region the streams have not yet succeeded in cutting definite channels, nor have they developed any complex system of tributaries. The storm waters escape along ill defined, concave depressions of a marshy character. These have their sources in the saucer shaped basins which are more or less inclosed by the irregular disposition of the swells. Water courses in the form of sloughs or marshes are typical of the Iowan drift topography, and are in striking contrast to the deep and open ravines that form so constant a feature of the Kansan drift surface.

Over all of the Iowan area in Benton county solitary bowlders of light colored granite are not infrequent. Some of these are of large size, but usually they are not so numerous or so large as to constitute topographic features of any great importance. Along the western portion of the county the surface is gently rolling, and in the townships of Monroe and Homer it passes into a very slightly undulating, almost level, plain. This type of surface is shown in figure 3. In the southern part of Kane township, the northern portion of Iowa and the northwest corner of Leroy, the surface becomes quite broken. The hills are somewhat subdued and in some places have received a deposit of loess several feet in thickness. Such a deposit of fossil bearing loess is exposed in a cut along the roadside between sections 12 and 13 of Iowa township. Over this area Iowan bowlders are quite numerous. The hills are plainly of pre-Iowan origin.

Pre-Iowan erosion was strong here on account of the proximity of the Iowa river. The thin sheet of Iowan ice that invades the area was not of sufficient depth, it did not carry sufficient materials, nor did its flow continue for a sufficient length of time to level down this deeply sculptured section over which it moved. The loess covering would suggest that the ice disappeared from these hills earlier than it withdrew from the adjacent portions of the Iowan plain.

In Cedar township the undulating prairie surface, dotted with frequent bowlders of respectable size and having numerous marshes occupying depressions between the low, rounded

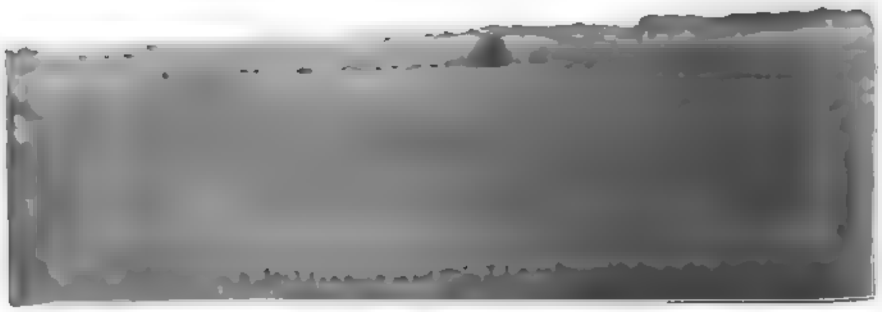

Fig. [illegible]. Prairie landscape over the Iowan drift plain; northwest of Keystone in Kane township.

prominences, extends right up to the bluff that overlooks the west bank of the Cedar river.

In the east central portion of Monroe township there is an elongated area, embracing about five hundred acres, that appears like an island of loess-covered Kansan standing in the midst of the typical Iowan plain. The long axis of this area extends from the northwest towards the southeast. Its topography is similar to that of the eroded Kansan plain such

as is encountered south of the Iowan margin. The slopes and crests of the hills are mantled with loess, and there is no trace of Iowan drift or Iowan bowlders or Iowan ice action to be seen upon it.

Another such peculiar area rises abruptly out of the Iowan plain in the northeast quarter of Big Grove township. This area is more than two miles in length and has a width of one and one-fourth miles. Its axis trends in the same general direction as that of the former. Like the former, too, this area is deeply dissected. The tops of the hills stand forty or fifty feet above the ravines and sixty to seventy feet above the general Iowan surface. Like the former area, also, there is a deep deposit of loess covering the summits and sides of the hills, and there are no Iowan bowlders and no indications of any kind to suggest that it had been covered by a glacier since the Kansan age.

When the early settlers came to this county they found these areas forest covered. Groves of native timber still remain over the steeper hillslopes. The presence of such a woodland area within its borders, in the midst of the treeless Iowan prairie, suggested for Big Grove township its name.

These island areas of Kansan features, that were surrounded but not submerged by the Iowan ice, form a part of a discontinuous chain of hills that extends in a southeasterly direction from near the middle of Monroe township to the northeast corner of the township of Florence. The abrupt elevations that overlook the town of Garrison from the northwest are members of this interrupted series. An area of very broken country, one-half mile to one and one-half miles in width, continues this line of hills from near the town of Newhall, in Eldorado township, to the valley of Prairie creek, in the northeast corner of Florence township. These latter hills rise sixty to eighty feet above the general altitude of the Iowan surface. They bear a thin mantle of loess, but, in the main, the rounded character of their contours and the presence of occasional bowlders of respectable size testify to a transient visit of a very thin body of Iowan ice. The presence of this peculiar belt of hills extending across the county would indicate that the ice

which moved over that particular area was so thin that it failed to overflow the island areas at all, and that it did not move over the other hills of this belt in sufficient depth and for a sufficient length of time to efface to any great extent their pre-Iowan features.

It is possible that the trend of this chain of hills represents the direction in which the ice-flow advanced and that this line is the result of a single attenuated portion near the frontier of the icy sea. However, it seems certain that the Iowan glacier became generally very thin towards its margin from the frequent occurrence of paha which are but another phase of the phenomena described above.

Paha is a name applied by McGee to isolated prominences that occur near the margin of the Iowan plain, and which were surrounded but not covered by the Iowan glacier. They rise abruptly out of the level prairie. The nucleus of these elevations in Benton county is a hill of undisturbed Kansan till. This drift is buried beneath a mantle of fine-grained, pebbleless material similar to that which crowns the hills along the Iowan border. Such prominences are not uncommon in Benton county and they are even more frequent to the eastward, in the counties of Linn, Cedar and Delaware.

A short distance northwest of the town of Norway an elongated paha ridge, one and one-half miles in length and one hundred rods in greatest width, extends from near the east side of section 13 of Saint Clair township in a southeast direction across section 18, and to near the middle of section 17 of the township of Florence. This conspicuous elevation stands about eighty feet above the surrounding plain. Its axis is a ridge of drift which at the top shows the leached, ferretto character of the old Kansan surface. At the northwest end of this hill the drift is overlain by a bed of loose sand six to ten feet in depth. Passing towards the southeast the material of this mantle becomes finer so that the covering of all but the upper end of the paha is typical loess. From the loess bank at the east end of this ridge Mr. Trojorsky obtains clay for the manufacture of brick and tile.

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Prairie creek is a typical representative of a class of streams in Iowa that have developed unsymmetrical basins, the channel of the master stream lying very close to the south side of the area which it drains. In this respect it resembles Wolf creek,* a few miles to the northwest, in Tama county, and also Clear creek and Old Man creek in the county of Johnson†. McGee‡ noticed this peculiarity in the basins of the eastward flowing streams over what he called the loess-drift area in central Iowa. Indeed, so frequently do the east and west coursing streams of Iowa have the longer affluents and the wider tributary area on the north side of their channels that Professor Calvin§ refers to this habit as a law that is generally true of such streams in the state.

Of the other streams that owe allegiance to the Cedar river, and which flow for the greater portion of their course in Benton county, the largest are Blue, Prairie and Bear creeks on the north, and Mud, Bear, Pratt, Hinkle and Rock creeks on the south. These are generally simple, consequent waterways without any complex series of secondary branches. They range in length from ten to fifteen or eighteen miles. They are all prairie streams. Their beginnings can be traced back to the swales and marshy meadows of the Iowan drift plain. Out from those boggy sloughs the water slowly filters, forming perennial springs. These unfailing fountains feed the larger streams with a constant supply of clear, pure water.

For some distance from its source the water follows lazily along shallow, grassy depressions that are bordered by no erosion formed banks. After a few miles each stream becomes established in a wide, partially drift filled valley that was formed prior to the advent of the Kansan glacier, and which neither that ice sheet nor the subsequent Iowan succeeded in completely obliterating. Even here, however, the bed of each of the present streams lies but a few feet below the general

*Iowa Geol. Surv., Vol. XIII. p. 205, Des Moines, 1903.

†*Ibid.*, Vol. VII, pp. 49-50, Des Moines, 1897.

‡Pleistocene History of Northeastern Iowa, p. 411, *et. seq.*, Washington, 1890.

§Iowa Geol. Surv., Vol. VIII, p. 212, Des Moines, 1898

NOTE.—For a discussion as to the cause of the development of such one-sided stream basins the reader is referred to volume VII, p. 51, and volume XIII, pp. 205-206, of this series of the Iowa Geological Survey reports.

Cedar river, and east and southeast to the Benton county line. In some cases the ridges extend in a general east and west direction and seem to be, in part at least, of the nature of dunes formed by obstructions which checked the velocity of dust laden currents of air during the time of retreat and since the withdrawal of the Iowan ice.

North of Urbana, in Polk township, the level surface of the Iowan plain stretches unbroken up to the northern border of Benton county. South of the Cedar river there is a rugged area lying between that stream and the main line of the old Burlington, Cedar Rapids and Northern railroad, embracing a part of Taylor township, the whole of Benton and the northern portion of Canton. The tops of the sand or loess crowned hills rise fifty to sixty feet above the marshes or basins or valleys that lie between them. In many of these deposits the loess contains fossils. A good exposure of such a fossil bearing bed may be seen in the east-central part of section 34, Benton township.

Where the surface is the most broken a fine forest of second growth timber covers the hills, and it would be well for the people of the county if the woodlands that yet remain might be judiciously preserved. While there is little in the topography of this region to suggest that it had suffered an invasion of the Iowan glacier, yet large bowlders of granite, gray or pink in color, are not rare over portions of this area. Such granite masses may be seen a short distance east of the wagon road near the west side of section 33 of Benton township, and they are especially abundant in the fields on either side of the road passing across the middle of sections 14 and 15 of the same township.

There is an abandoned river channel, one-half mile to one mile in width, that extends in a southeasterly direction from the site of the old town of Benton city, on the Cedar river, to the southeast corner of Benton township. It meets the present channel of the Cedar river again about one-half mile east of the Benton-Linn county border. This old valley is known locally as "Sand Prairie." Beds of sand like river bars abound over the lowlands, and deposits of similar materials crown the summits

of the bordering bluffs that rise to a height of seventy or eighty feet on either side. The Cedar river doubtless occupied this waterway at one time, but for some reason its waters have since carved a deeper and more circuitous channel through resistant Devonian limestone, leaving this abandoned valley a witness to the changes, but affording slight explanation as to the cause of such desertion.

Between Sand Prairie and the Cedar river circular mounds and oblong earthworks of some prehistoric inhabitants are con-

FIG. 5. Lake in the Iowa drift area, section 15, Benton township. The low, bordering hills were, until recently, covered with forests.

spicuous. Numerous stone hatchets, flint arrowheads, scrapers and other implements of early man have been found over the region by Mr. Thomas Carver, of Shellsburg, and other enthusiastic collectors. Near the northwest corner of section 15 of Benton township there is a glacial lake that covers an area of three and one-half to four acres, and which formerly was of much larger size. See figure 5. It is surrounded by low, forest clad hills and is situated one hundred feet above the flood plain of the Cedar river and twenty rods south of the bluff that

borders the valley. About three-fourths of a mile southwest of this lake there are a number of mounds composed of rather fine-grained sand, and disposed in a line along the crest of a divide that is bordered on either side by a deep ravine. Another group consisting of ten or twelve circular mounds arranged about an oblong ridge six or seven rods in length occurs a short distance to the southeast of the lake mentioned above. Excavations in these mounds have furnished a few poorly preserved fragments of human bones. The mounds are probably tumuli where men of a departed race, with a keen sense of the beautiful withal, built the graves of their fathers beside the quiet waters of this charming lakelet, and overlooking the valley of the river where picturesque bluffs of woodland and scarped cliffs of limestone make beautiful its bordering banks.

The area embraced between the bend of the Cedar river and the abandoned valley of Sand Prairie is the scenic portion of the county. For purposes of tillage the land can not be compared with the deep, black soil of the wide prairie that surrounds it at some distance on every side. The steep hillslopes and sand covered crests should never be deforested, nor should the plow of the too enterprising farmer be allowed to convert these uniform slopes into angular trenches and rain washed gulleys. If the more densely wooded portion of this area, so convenient to the towns of Vinton, Shellsburg and Urbana, could be preserved as a picnic ground or public park, accessible to all for purposes of pleasure and recreation and for the beneficent influence which objects of natural beauty so graciously afford, it would prove a constant source of satisfaction and enjoyment to the enlightened people of Benton county.

ALTITUDES.

The following table of elevations, compiled from Gannett's Dictionary of Altitudes in the United States, gives the height above tide of the roadbed at the railway station in the most of the towns of Benton county:

	NAME OF STATION.	FEET.
1.	Shellsburg	774
2.	Atkins	841
3.	Norway	792
4.	Walford	806
5.	Vinton	810
6.	Newhall	877
7.	Watkins	812
8.	Mt. Auburn	863
9.	Garrison	859
10.	Van Horn	951
11.	Blairstown	839
12.	Luzerne	897
13.	Keystone	883
14.	Belle Plaine	824

From an examination of the table of altitudes it will be seen that in the northern part of Benton county the surface slopes towards the southeast, while in the southern portion the inclination is almost due eastward. The highest point of the area is probably in the western part of Monroe township, on the divide between the Cedar and the Iowa rivers. At the town of Dysart, just across the line in Tama county, the altitude is 968 feet. From this point the line of greatest elevation extends in a general southeast direction to Van Horn, thence east to Newhall. It then bends a little south of east, passing about one and one-half miles south of the town of Atkins.

The Shellsburg topographic sheet, published by the United States Geological Survey, gives the altitude along the flood plain of the Cedar river in the eastern portion of Benton county as about 760 feet above the mean sea level, and the elevation of the tops of the hills in that portion of the county at 960 feet. It seems probable that the measure of the extreme range between the highest and the lowest elevations in the county would not much exceed 210 feet.

DRAINAGE.

Two master streams, the Cedar river and the Iowa, control the drainage of Benton county. The northeastern and the southwestern portions of the county are pretty well dissected by stream channels, and consequently have a fairly thorough surface drainage. Over a large portion of the intervening area, however, marshes are not infrequent. Many of the sloughs have not yet been converted into corn fields, nor have all of the swales been properly tiled and put under the plow.

These marshes are the contracted remnants of once larger glacial lakes. They represent the last stages in the passing of these lakes from which the water has been banished by the development of slight drainage, by the shrinking of the ground water, by filling with material borne by the winds and washed by the rains from the bounding slopes, and by the accumulation of the imperfectly decomposed remains of moisture loving plants which for many generations flourished around the shallow margin of these prairie pools.

Some of the marshes still furnish congenial conditions for the growth of cat-tails and rushes. The most of them, however support a luxuriant growth of swamp grass and sedges. During the summer months the uniformly rich, green color of these grassy patches is broken only where a solitary water hemlock spreads aloft its delicate umbels or a swamp milkweed unfolds its purple flowers. Such areas are usually left for native meadow, or fenced and utilized for purposes of pasturage.

The Iowa river.--The Iowa river receives the run-off from an area of about seventy-five square miles in the southwest corner of the county. It enters Benton from Tama county about the middle of the west side of section 31 of Iowa township. It cuts across the southwest corner of this section and enters Iowa county about the middle of the south side of the same section. After passing south for a distance of one-fourth of a mile the channel bends northward and once more enters Iowa township near the southwest corner of section 32. It meanders near the south side of this section for one-half mile, then bending further southward it again leaves Benton county and returns no more to its borders.

Along this portion of its course the river flows in a channel of pre-Kansan age which was probably carved in the indurated rocks before the advent of the Glacial epoch. Wells that have been put down over the flood plain of the Iowa in Benton county show that the preglacial channel was more than two hundred feet deeper than the bed of the present stream. The width of the ancient valley has not been definitely ascertained, but well borings would indicate that it was probably not less than five or six miles. The waters of the present river flow in a broad flood plain nearly two miles in width. The valley is bordered by bluffs of Kansan drift that stand sixty to eighty feet above the bed of the stream. At none of the numerous meanders of the river has the current cut away the bordering hills to such an extent as to expose the indurated rocks which formed the banks of the preglacial valley.

Stein creek.—The only tributary to the Iowa river whose waters are largely collected from Benton county is Stein creek. This stream rises in the ill drained swales of the Iowan plain near the southern border of Kane township. It flows in a southeasterly direction across Iowa township, crossing the county line near the southwest corner of section 36. It drains a few square miles along the south side of the township of Kane, and the greater portion of the surface of Iowa township. Its waters flow in a pre-Kansan valley bordered by hills of drift of Kansan age. At no point in this portion of the county are indurated rocks exposed in the banks of the stream. The channel of Stein creek has a flood plain three-fourths of a mile in width and it is bounded by bluffs sixty feet in height. The hills that form the west bank of the valley are higher and more precipitous than those that border it on the east.

The Cedar river.—The Cedar river enters Benton county, from Black Hawk, near the northwest corner of section 6, township 86 north, range 10 west. It flows for about two miles in a direction a little south of east and then bends nearly due south for a distance of three miles. Along this portion of its journey the waters are confined in a comparatively narrow channel which is bounded for much of the distance by abrupt ledges of limestone. Near the middle of the west side of section 21 of

Harrison township the river bends westward, debouching in a broad, drift bordered valley one and one-half to two miles in width which it follows down to the city of Vinton.

This broad valley continues toward the southeast from Vinton past the town of Shellsburg and beyond the limits of the county. It is bordered on the north by rather abruptly sloping hills, but on the south the bed of the channel merges by a gentle gradient into the undulations of the Iowan plain. Instead of following the direct course in the channel already formed, the bed of which is only a few feet higher than its own flood plain, the Cedar river swings northward at Vinton and continues to flow in that direction up to the southeast corner of section 9 of Taylor township. It then changes to a southeasterly trend for two and one-half miles, when it again bends to the northeast for one mile, and then with a swing to the southeast and east it reaches the old town of Benton City, about the middle of the west side of section 20, Benton township. At this point once more an opportunity was presented for the Cedar river to appropriate an old preglacial channel, the Sand Prairie described above. With inexplicable perversity it again turns aside from the ready formed waterway and choosing the longer course and more difficult route, it swings in a broad curve two and one-half miles farther north, carving a new channel one hundred and twenty-five to one hundred and fifty feet in depth in the hard limestones of the Cedar Valley stage. The river leaves the county near the middle of the east side of section 13 of Benton township. It again meets the preglacial channels not far from the town of Palo, a short distance east of the Benton county line. By the erratic course which it follows from Vinton to Palo the river traverses a journey of eighteen miles to shorten the distance to its mouth by one-half that number of miles. It carves a channel to a depth of more than one hundred feet in hard limestones in order to avoid the shallow cutting and ready erosion that would have been required by the more direct route.

In this peculiar action the Cedar exemplifies the anomalous behavior of many of the rivers of eastern Iowa portrayed so graphically by McGee.* It resembles the course of the

*Pleistocene History of Northeastern Iowa, 11th Ann. Rept., U. S. Geol. Surv., p. 218 *et seq.*, Washington, 1891.

Wapsipinicon† a few miles to the northeast, in Buchanan county, and that of the Iowa river‡ about the same distance to the southeast, as described by Professor Calvin.

The cause of such behavior on the part of these rivers can only be conjectured. It seems probable, however, that the explanation must in some way be connected with the invasion of the region by the glaciers. It is probable, too, that in Benton county the Pre-Kansan ice sheet was responsible for the development of the present channel of the Cedar river from the vicinity of Vinton to the village of Palo. The evidence for such an assumption lies in the fact that at several points along this portion of the channel, drift of Kansan age forms the bounding hills and continues down to the fluviatile deposits of the flood plain. It may be possible that when the Pre-Kansan ice sheet overspread this region, and while it occupied the old channels between Vinton and Palo, mentioned above, a super-glacial stream cut through the ice and became established over the newer portions of the present channel.

In order that the course of this new stream might be made permanent the ice must have maintained the same position relative to the stream during a sufficient length of time for the water to carve the newer portions of the channel to a depth a little below the altitude at which the surface of the abandoned valleys was left when the ice retreated. In this manner the return of the river to either of the preglacial channels along this particular portion of its course would be prevented.

Prairie creek.—Prairie creek drains a larger area in Benton county than any other tributary to the Cedar river. It rises in the marshes of Kane and Homer townships. It flows a little east of south for a dozen miles, in a direction nearly parallel with the channel of Salt creek, which lies ten miles to the westward, and with the valley of Stein creek nearer at hand. However, instead of continuing parallel with those streams and rendering tribute to the Iowa river, its channel bends abruptly towards the east near the northwest corner of section 16 of Leroy township. It swings two miles to the southward as it crosses near the middle of Saint Clair township, and again

† Calvin: Iowa Geol. Surv. Vol. VIII, p. 210, Des Moines, 1897.

‡ Calvin: Iowa Geol. Surv., Vol. VII, pp. 47-48, Des Moines, 1896.

bends as far to the north as it passes across the township of Florence. From the elbow in Leroy township the channel of Prairie creek maintains a trend that is practically parallel with the valley of the Iowa river up to the point where it leaves the county, near the southeast corner of section 12 of the latter township. Its waters meet those of the Cedar river about a dozen miles further eastward, in Linn county.

Prairie creek has a longer flow in Benton county than any other stream, traversing a distance of over forty miles. It embraces in its basin the larger portion of Kane township, the southern part of Big Grove, the northeast corner of Iowa, practically the whole of Union and Saint Clair, the larger portion of Leroy and Florence and the southern part of Fremont and Eldorado townships. It drains an area of more than one hundred and eighty square miles.

Down to where the stream makes its abrupt bend to the east, in Leroy township, the banks that bound the channel are low, symmetrical hills composed of drift material. From this elbow to the point where the creek leaves the township the broad valley is overlooked on the south by the more abrupt ridges which constitute the Iowan drift border. To the north the slopes rise gently up to the level of the Iowan plain. As the creek passes across Saint Clair and Florence townships the southern boundary of the channel becomes more and more poorly defined, owing to the more southern trend of the ridges of the Iowan drift margin. At the same time the northern limits of the valley become more prominent. Beginning at Watkins the stream is overlooked on the north by the paha ridge above described, and further east by the Norway paha, and still further eastward by the abrupt hills which in the county terminate the discontinuous line of ridges that cuts diagonally across it in a northwest-southeast direction.

Throughout the whole of the eastward flowing portion of its course in Benton county the bed of Prairie creek follows parallel with, and only one to two miles distant from, the divide that separates its basin from that of the Iowa river. Its affluents from the south are short, insignificant branches none of which are of sufficient consequence to merit a name. From the north

it receives tribute from Weasel, Buffalo and Mud creeks, the latter being more than a dozen miles in length.

Prairie creek is a typical representative of a class of streams in Iowa that have developed unsymmetrical basins, the channel of the master stream lying very close to the south side of the area which it drains. In this respect it resembles Wolf creek,* a few miles to the northwest, in Tama county, and also Clear creek and Old Man creek in the county of Johnson†. McGee‡ noticed this peculiarity in the basins of the eastward flowing streams over what he called the loess-drift area in central Iowa. Indeed, so frequently do the east and west coursing streams of Iowa have the longer affluents and the wider tributary area on the north side of their channels that Professor Calvin§ refers to this habit as a law that is generally true of such streams in the state.

Of the other streams that owe allegiance to the Cedar river, and which flow for the greater portion of their course in Benton county, the largest are Blue, Prairie and Bear creeks on the north, and Mud, Bear, Pratt, Hinkle and Rock creeks on the south. These are generally simple, consequent waterways without any complex series of secondary branches. They range in length from ten to fifteen or eighteen miles. They are all prairie streams. Their beginnings can be traced back to the swales and marshy meadows of the Iowan drift plain. Out from those boggy sloughs the water slowly filters, forming perennial springs. These unfailing fountains feed the larger streams with a constant supply of clear, pure water.

For some distance from its source the water follows lazily along shallow, grassy depressions that are bordered by no erosion formed banks. After a few miles each stream becomes established in a wide, partially drift filled valley that was formed prior to the advent of the Kansan glacier, and which neither that ice sheet nor the subsequent Iowan succeeded in completely obliterating. Even here, however, the bed of each of the present streams lies but a few feet below the general

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*Iowa Geol. Surv., Vol. XIII. p. 205, Des Moines, 1903.

†*Ibid.*, Vol. VII, pp. 49-50, Des Moines, 1897.

‡Pleistocene History of Northeastern Iowa, p. 411, *et. seq.*, Washington, 1890.

§Iowa Geol. Surv., Vol. VIII, p. 212, Des Moines, 1898

NOTE.—For a discussion as to the cause of the development of such one-sided stream basins the reader is referred to volume VII, p. 51, and volume XIII, pp. 205-206, of this series of the Iowa Geological Survey reports.

level of the region through which it flows. Along this portion of their courses there is exposed at rare intervals ledges of indurated rock. Such outcroppings are exceedingly infrequent, however, and are limited to the north half of the county, with the exception of a small area adjacent to the town of Shellsburg.

GEOLOGICAL FORMATIONS.

General Relations of Strata.

That portion of the ancient geological history of Benton county directly accessible to observation is written on the rocks of the Middle Devonian series, while the more recent records are preserved in the deposits of the Pleistocene.

In the Middle Devonian series is included the most of the beds of indurated sediments, the limestones and the shales, which form the foundation upon which the soil and superficial materials of the region are spread. Each successive layer of this foundation was at one time the floor of the ancient sea and makes up a separate page in the history of our land and of its life. Each successive stratum was in part constructed from the ruins of preëxisting lands, and contains the remains of forms of life that peopled the sea as age succeeded age.

Outcrops of these rocks are encountered only in the northern and northeastern portions of the county. Over the southern and southwestern portions they are deeply buried beneath a covering of drift. There is little doubt that the rocks which immediately underlie the till over the most of the southern portion of the area also belong to the Devonian system, while those upon which the drift is spread in the southwestern corner of the county belong to the Kinderhook stage of the Mississippian series.

In the regolith,* or mantle of incoherent, superficial materials is recorded much later chapters in our county's varied and eventful story. The materials of this mantle testify to the long occupation of our area by immense glaciers and to the desolation that followed in their train. They bear witness to the flooded streams and river torrents that accompanied the melting of the ice, and to the long genial period of interglacial conditions that intervened between the successive ages during which arctic winter reigned.

A small part of this rock mantle is composed of the residual products resulting from the degeneration of indurated rocks during the long interval that elapsed between the elevation which closed the deposition of sediments, and the advent of the Pleistocene period. This geest or residuum has, for the most part, been intimately mixed with the many times greater quantity of foreign detritus that was transported by the ice from further north and left as a legacy to the region over which it spread.

The following table shows the stratigraphic position of the geological formations known to be exposed in Benton county:

*Merrill: Rocks, Rock Weathering and Soils, p. 299.

TABLE OF FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
		Recent.	Recent.	Swamp, Æolian, Alluvial deposits
				Loess.
Cenozoic	Pleistocene.	Glacial.	Iowan.	Iowan till.
			Yarmouth.	Buchanan gravels.
			Kansan.	Kansan till.
			Aftonian.	Aftonian gravels
			Pre-Kansan	Pre-Kansan till.
	Carboniferous.	Lower Carboniferous or Mississippian.	Kinderhook.	Shale.
Paleozoic	Devonian.	Middle Devonian.	Cedar Valley	
				Fayette.
			Wapsipinicon.	Coggan.

Middle Devonian Series.

WAPSIPINICON STAGE.

From the synoptical table it will be seen that the indurated rocks which are exposed in Benton county belong to the Middle Devonian series, and of this series there are represented the Wapsipinicon and the Cedar Valley stages. Of the deposits of the Wapsipinicon stage the known rocks of the county belong to two sub-stages, the Fayette and the Coggan.

The assemblage of layers that have been grouped under the Coggan sub-stage includes a few feet of buff, magnesian limestone. This bed is usually somewhat massive but not infrequently, especially in the uppermost part, it shows more or less distinct lines of stratification. The name of Coggan was given to this sub-stage by Professor Norton* from the town of that name in the northeastern part of Linn county, at which place the rocks of this horizon are well exposed.

The Fayette sub-stage embraces a group of strata composed of a series of diverse limestones. Some of these are very dense and fine-grained. Others are made up of masses rather coarse in texture. Some contain numerous fragments of brachiopod and molluscan shells, while others are barren of any fossil remains. At some horizons the rocks are of a dark drab color, and at others they are almost white. However, they are all in common more or less completely shattered and brecciated. These beds are well exposed near the town of Fayette where this particular phase of the Devonian strata is typically developed. At this place McGee applied the name Fayette breccia to this series of limestones.

Coggan beds.—The rocks of the Coggan sub-stage are exposed in Benton county along the east side of a narrow ridge for a distance of more than one mile. This ridge is only ten or twelve rods in width. Its top stands about twenty feet higher than the adjacent upland surface, and eighty feet above the bed of Cedar river. Its northeastward facing bluff overlooks the lower portion of the channel of Pratt creek and forms the west bank of the Cedar river for several rods below the point where the waters of the creek and the river meet.

On the west side of the wagon road, near the middle of the east side of section 36, Cedar township, Mr. Wallace has opened a quarry in which is shown the following succession of beds:

*Iowa Geol. Surv., Vol. IV, p. 188.

		FEET.
6.	Dark colored soil, fine-grained, without pebbles..	1
5.	Bed of light colored, brecciated limestone, the fragments imbedded in a matrix of gray material; without any trace of lamination planes or of fossils...........................	12
4.	Bed of gray, calcareous shale; without fossils...	2
3.	Ledge of massive, yellow colored stone, somewhat arenaceous near the middle, but composed for the most part of impure magnesian limestone; containing no fossils................	6
2.	Layer of yellowish-gray, magnesian limestone, fine-grained like No. 1, below; without fossils.	2½
1.	Ledge of buff, earthy limestone, very fine-grained, slightly banded in appearance and showing imperfect lines of division into layers eight to ten inches in thickness; without fossils......................................	2

The characters of the above layers are illustrated in figure 6. In the section numbers 1 to 3 inclusive represent the Coggan sub-stage as the rocks of this horizon are exposed in Benton county. They are uniformly yellowish-gray in color and very fine-grained, sub-crystalline in texture. In composition they are impure, magnesian limestone. They present the appearance of dolomite, but the process of dolomitization is not so complete but that effervescence is quite prompt upon the application of cold hydrochloric acid. In the rocks of this horizon, in the counties of Linn and Cedar, Professor Norton found a few fossils in the form of casts or moulds, but no traces of fossils in any form were seen in Benton county. Number 4 is a band of gray, non-fossiliferous shale which gradually blends above into the lower portion of the overlying bed of brecciated limestone. In Buchanan county, the Independence shale occupies a position immediately below the deposits of the Fayette breccia. There also occurs in Linn county a bed of shale, designated by Norton as the Kenwood, which occupies a corresponding horizon. It is possible that this narrow shale band, number 4 of the section, represents the attenuated margin of the Independence shale deposit. The thinness of the band, the absence of fossils, and the fact that this is the only known exposure in the county of such a shale horizon render impossible the satisfactory correlation of this member with the Independence shale. It is thought best to consider number 4 at this place as a local de-

velopment of argillaceous material at the beginning of the deposits of the Fayette sub-stage. Number 5 is a thick bed of light colored, thoroughly brecciated limestone in which no sign of bedding planes has been preserved, and which contains no trace of fossils. The face of this ledge shows numerous, small cavities, the cementing material not completely filling the spaces between the angular rock fragments. These fragments

FIG. 6. Exposure in Wallace's quarry, near the southeast corner of section 36, Cedar township. The heavy ledge at the base represents the Coggon beds; the overlying, unstratified materials belong to the Lower Davenport phase of the Fayette breccia.

vary from one or two inches to one foot or more in diameter. They present the appearance of having been coated with quite fluid calcareous mud before the deposit of interstitial material cemented the pieces solidly together. The fragments are composed of very hard, fine-grained, slate colored limestone enclosed n a matrix a little lighter in color.

About three-fourths of a mile southeast of Wallace's quarry, near the southwest corner of section 31 of Harrison township, Aungst Brothers operate a quarry in the west bluff of Cedar river. At this point the following section is shown below the superficial deposits:

		FEET.
2.	Brecciated limestone, gray in color, the angular fragments usually small, and very fine-grained in texture; without fossils	20
1.	Massive ledge of buff, magnesian limestone which is very hard and fine-grained, divided by imperfect lines of bedding into layers one to two feet in thickness; without fossils	12

In the above section number 1 is the equivalent of numbers 1 to 3 inclusive of the Wallace quarry section. At this place, however, the stone is more purely dolomitic. It is very dense, almost crystalline in texture, and is of excellent quality for lime burning or general masonry. Mr. Aungst has tunneled beneath the overlying breccia and excavated chambers ten to fifteen feet in depth for a distance of one hundred feet back under the hill. The face of the quarry extends for several rods along the bank of the river. Number 2 of the above section corresponds with number 5 in the section of Wallace's quarry. This member represents the basal portion of the Fayette breccia. In the upper part it probably passes into the Lower Davenport beds of Professor Norton*, which he designates as the second phase of the Fayette breccia. The rocks in the two exposures are quite similar in lithology and in the absence of fossils. The layer of shale, which at Wallace's quarry lies between the magnesian bed at the base and the brecciated limestone above, is wanting in the Aungst quarry exposure.

Fayette breccia.—A low ledge of thoroughly brecciated rock of which the fragments are small and imbedded in a buff colored matrix of coarser texture outcrops in the north bank of Pratt creek, near the southwest corner of section 22 in Cedar township, and at a few other points along the valley of this same

* Norton: Geology of Linn County. Iowa Geol. Surv., Vol. IV, p. 160.

stream. This ledge is also the equivalent of number 2 of the Aungst quarry section, and represents the most northerly extension of the rocks of this horizon in Benton county.

At a point along the Aungst quarry exposure the old Burlington, Cedar Rapids and Northern Railway Company has made a cut through the ridge above mentioned and exposed a vertical height of about thirty-five feet of limestone on either side of the track. The level of the rails in this cut is about the same altitude as the top of the brecciated bed in the Aungst quarry section. The rock exposed in the cut is shattered throughout. This bed together with number 2 of the Aungst quarry section gives a thickness of more than fifty feet of the Fayette breccia at this place. The following section will illustrate the character of the rocks exposed in the cut, although there is no definite line of division between the two members as given below:

	FEET.
2. Brecciated limestone in which the long axes of some of the fragments are four to eight feet in length. The larger masses are a drab color, and lie among smaller, light gray or yellowish fragments, none of which have been cemented together. The following fossils are quite abundant in the larger masses: *Spirifer pennatus*, the finely-striated, Independence type of *Atrypa reticularis*, *Gypidula comis*, *Atrypa aspera* var. *occidentalis*, *Orthis iowensis*, *Stropheodonta demissa* and a species of Chonetes resembling *C. cancellatus*................	20
1. Brecciated limestone in which the fragments are from a few inches to three or four feet in length, becoming larger and more fossiliferous in the uppermost part. The following fossils were present: Gyroceras sp. *Spirifer pennatus*, *Gypidula comis* and the finely-striated form of *Atrypa reticularis*..............	13

In the above section number 2 probably represents the *Spirifer pennatus* beds of Calvin which, in the classification of Professor Norton,* constitutes the uppermost phase of the Fayette substage.

Number 1 corresponds with the third phase of the Fayette breccia as defined by Norton in the adjoining county of Linn.†

*Norton: Iowa Geol. Surv., Vol. IV, p. 161. Des Moines.
†Ibid., p. 160.

It includes the Gyroceras beds* as delimited by Professor Calvin in the report on Buchanan county.

The cause and the process by which these brecciated beds were formed are alike somewhat obscure. Professor Geikie† says that true breccias arise from the superficial disintegration of rocks. They may be formed of talus blocks or cliff debris which gradually slide down a slope below an escarpment, or which may be launched forward by a landslip. The materials may accumulate either subaerially, or under water when the cliff descends at once into the sea. In any case the fragments have not been transported any great distance, nor have they been subjected to the action of running water.

The term breccia is also applied to masses of angular rock fragments whose formation is connected in some way with volcanic eruptions, or with the flow of more or less fluid lava subsequent to such eruptions. Breccia has also been formed where strata within the earth's crust have been subjected to trains resulting in movements that produced crushing or dislocation. The angular fragments which originated in any of the above ways may or may not have subsequently been consolidated by the infiltration of some cementing materials.

Professor Norton‡ assumes that the brecciation of the rocks of the Fayette sub-stage in Iowa has probably been accomplished by the crumpling of the strata resulting from lateral pressure. The facts which are revealed in the most of these beds in Benton county are in harmony with such a mode of rock fracture. There can be traced every gradation of disturbance from that evidenced by the presence of joints without displacement of the rock masses, to that of profound shattering where the beds are made up of fragments of diverse limestones promiscuously intermingled.

In the *Spirifer pennatus* horizon the beds at some exposures are considerably broken, but there is usually small disarrangement of the fragments. Frequent narrow veins of calcite extending in various directions at right angles to the planes of bedding show where small fractures have been healed. At outcrops not far distant the corresponding layers have not been

*Calvin: Iowa Geol. Surv., Vol. VIII, pp. 225-227.
†Geikie: Text-book of Geology, Vol. I. p. 164. 4th Edition.
‡Norton: Iowa Geol. Surv., Vol. IX, pp. 445-446.

disturbed. Lower down there are encountered beds in whi[illegible] the materials are uniformly shattered, as in the lower port[illegible] of the Railroad Cut exposure, but it is often possible, even her[illegible] to trace the planes of the original layers by the lithologi[illegible] characters of the fragments that occur at the successive leve[illegible] Still lower down the rocks are profoundly brecciated and frag- ments of dissimilar limestones are brought into juxtapositio[illegible] Sharply angular pieces of various texture, color and size ar[illegible] cemented together to form the ledges which constitute th[illegible] Lower Davenport beds of the Fayette breccia. Certain phase[illegible] of the Lower Davenport breccia seem difficult of explanatio[illegible] by assuming crushing as the mode of formation, and seem to indicate a talus origin. McGee* noticed that the strata which are involved in the beds of the Fayette breccia were confined to those horizons in which the layers show more or less crumpling or distortion. He considers these two phenomena to be related, and suggests that the forces which accomplished the flexing of the strata were the same that caused the brecciation of the beds. The time of such movements he thus fixes at about the close of the period of their own deposition.

The following fossils were collected at the Railroad Cut exposure where the last section was made:

Fistulipora constricta Hall.
Stropheodonta demissa Conrad.
Pholidostrophia nacrea Hall.
Orthothetes chemungensis Conrad.
Chonetes cf. *cancellatus* Calvin.
Productella subalata Hall.
Orthis iowensis Hall.
Pentamerella arata Conrad.
Gypidula læviuscula Hall.
Gypidula comis Owen.
Atrypa reticularis Linn. Independence type.
Atrypa aspera var. *occidentalis* Hall.
Spirifer pennatus Owen.
Spirifer asperus Hall.
Paracyclas elliptica Hall.
Pelecypods 2 sp's.
Gyroceras sp.
Phacops rana Green.

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*McGee: Pleistocene History of Northeastern Iowa, Eleventh Annual Report, U. S. Geol. Surv., pp. 337-338.

See also Calvin's report on the Geology of Mitchell County, Iowa Geol. Surv., Vol. XIII, p. 316.

In the counties of Cedar and Linn Professor Norton found the Otis limestone and the Independence shales intervening between the Coggan beds at the base of the Iowa Devonian and the Fayette breccia which forms the uppermost member of the rocks of the Wapsipinicon stage. Deposits of the Otis and Independence sub-stages seem to be entirely wanting in Benton county, unless those of the latter are represented by number 4 of the Wallace quarry section.

At the old Bliss quarry, on land owned by the Iowa Paint Company, an exposure in the south bank of Prairie creek, near the northeast corner of section 10, Taylor township, shows the following succession of beds:

		FEET.
5.	Shattered limestone, light gray in color, the fragments irregular in shape and size, and containing few fossils	8
4.	Talus covered ledge	12
3.	Bed of light gray limestone, in broken layers from three to six or seven inches in thickness; containing *Orthis iowensis* and *Atrypa reticularis*	1⅔
2.	Ledge of gray limestone made up of imperfect layers two to eight inches in thickness; bearing *Orthis iowensis*, *Atrypa reticularis* and two or three species of pelecypods	4
1.	Rather massive bed of light gray limestone which is cut into rhomboidal blocks by numerous oblique joints, some of which show excellent examples of slickensides. Where exposed the material weathers quite readily into small, irregular fragments. Numerous fossils occur in this member, among which the following are abundant: large, robust forms of *Spirifer pennatus*, *Spirifer bimesialis*, *Cyrtina hamiltonensis*, *Orthis iowensis*, *Atrypa reticularis*, *Gypidula comis* and, near the base, a species of Gyroceras	8

In the above section number 1 represents the *Spirifer pennatus* beds, and it is the probable equivalent of number 2 of the section in the railroad cut above the Aungst quarry exposure. The entire bed is cut by numerous joints and is profoundly shattered, but the position of the fragments has not been greatly displaced nor have the pieces been cemented together. The fractured condition of the bed, the numerous

joints and the presence of slickensides testify to the severe strains and crushing forces to which the strata have been subjected.

Some years ago when the Iowa Paint Company operated at Vinton the material of this lower member of the Bliss quarry was pulverized and used as the basis in the manufacture of paint. The company has since moved its plant to Fort Dodge, and gypsum is now utilized in the place of limestone in their present process of paint manufacture.

Numbers 2 to 5 inclusive in the above section represents the basal portion of the Cedar Valley stage. The fossil content of this zone could not be well made out at this place owing to the large portion of the face of the ledge that was concealed by talus.

CEDAR VALLEY STAGE.

Near the northwest corner of section 27 of Taylor township, a quarry has been opened in the east bank of Mud creek, on land owned by Mr. Quinn. At this place the following succession of layers is exposed:

		FEET.
10.	Dark colored soil, fine-grained and without pebbles	½
9.	Gravel and sand, stained a reddish-brown color.	2
8.	Bed of limestone composed almost wholly of fragments of corals among which the following forms are abundant: *Acervularia davidsoni*, *Cladopora iowensis*, Favosites sp., *Cystiphyllum americanum*, *Ptychophyllum versiforme* and Cyathophyllum sp., together with numerous teeth of *Ptyctodus calceolus*	5
7.	Layer of rather hard, gray limestone which weathers into thin pieces, and contains numerous crinoid remains, besides Favosites sp., Cyathophyllum sp., *Orthis iowensis* and *Spirifer parryanus*	3
6.	Bed of very hard, light gray limestone which upon weathering shows layers four inches to one foot in thickness, and contains *Spirifer fimbriatus*, *Spirifer pennatus*, *Orthis iowensis*, *Atrypa reticularis*, *Atrypa aspera* var. *occidentalis*, species of Cladopora and Favosites together with large teeth of *Ptyctodus calceolus*.	6

FEET.

5. Layer of very hard, gray colored limestone composed largely of fragments of brachiopod shells among which the following are conspicuous: *Orthis iowensis*, *Spirifer pennatus*, *Atrypa reticularis* and *Atrypa aspera* var. *occidentalis*. Species of Cladopora and Favosites were also seen 1⅓
4. Layer similar to number 5 above but with the shells more finely comminuted 1¼
3 Zone of drab colored limestone in the form of a second coral reef which is less compact and not so crowded with coral remains as number 8 above. The member contains *Acervularia profunda*, Favosites sp., Cystiphyllum sp., and Cyathophyllum sp., besides *Orthis iowensis* and *Spirifer pennatus*.......... 1
2. Bed of fine-grained, white limestone which shows a bluish tinge in a fresh ledge, containing numerous nodules of chert, and weathering into layers from a few inches to two or three feet in thickness. This member is much shattered in places, and contains the following fossils: crinoid fragments, *Atrypa aspera* var. *occidentalis*, *Spirifer pennatus*, small individuals of *Stropheodonta demissa*, large teeth of *Ptyctodus calceolus* and a large species of Gomphoceras.............................13
1. Layer of very hard limestone, bearing chert nodules and containing remains of crinoids, together with *Favosites* cf. *placenta*, Favosites sp., Cyathophyllum sp., *Atrypa reticularis*, *Atrypa aspera* var. *occidentalis*, *Spirifer bimesialis*, *S. pennatus*, *Cyrtina hamiltonensis*, *Orthis iowensis* and teeth of *Ptyctodus calceolus* 1½

In the above section numbers 1 and 2 probably belong to the horizon of the *Spirifer pennatus* beds. Together these members correspond with number 2 in the Railroad Cut exposure and with number 1 of the Bliss quarry section. The stone is quite hard and fragments of broken disks and plates of crinoids are not rare throughout the portion of the bed that is exposed. The rocks of this horizon are represented in figure 7. They are quite variable in exposures not widely separated. At some points they are undisturbed and quite hard, but generally they are much shattered. At the Quinn exposure the stone from

this member is the most durable that the quarry produces. It is used extensively in the town of Vinton for foundation work and rough masonry.

Number 3 represents the *Acervularia profunda* zone which occupies a position at the very base of the Cedar Valley stage. It is the probable equivalent of the Phillipsastrea horizon in the adjacent county of Buchanan, although that coral was not seen in the area under consideration. Associated with *Acervularia profunda* at Quinn's quarry are Cystiphyllum sp., Cyathophyllum sp., Favosites sp. and a spherical Stroma-

FIG. 7. Exposure of the lower portion of the Cedar Valley limestone in the Quinn quarry, near Vinton. The *Acervularia davidsoni* coral reef appears at the top.

toporoid. This coral-bearing bed marks quite a constant horizon twelve to fifteen feet below the *Acervularia davidsoni* coral reef wherever the deposits of the lower portion of the Cedar Valley stage are exposed in Benton and the neighboring counties.

Numbers 4 to 7 inclusive are composed of layers of firm, gray limestone which are made up largely of fragments of brachiopod shells and coral remains. The adjacent layers are generally

separated by narrow partings of calcareous shale. Of the fossils that are characteristic of these beds *Orthis iowensis*, *Atrypa reticularis* and a species of Cladopora, resembling *C. iowensis* Owen, are found throughout all of the members. *Acervularia davidsoni* and *Spirifer parryanus* are not infrequent in number 7, while *Spirifer pennatus* and *Atrypa aspera* var. *occidentalis* are common in the lower members.

Number 8 is the reef of corals composed in large part of coralla of *Acervularia davidsoni* with which are associated *Favosites alpenensis*, Favosites sp., *Cladopora iowensis*, *Cystiphyllum americanum*, Cyathophyllum sp., *Heliophyllum halli* and *Ptychophyllum versiforme*. At this place the corals are not so closely crowded and the reef is not so compact as it is further north and west in Benton county, the average thickness being about twenty-four inches.

This zone, which will be designated as the *Acervularia davidsoni* coral reef, is one of the best marked and most constantly and uniformly developed layers of the Cedar Valley limestone in the state. It appears at this particular horizon in the counties of Scott and Muscatine, to the southeast, in Buchanan and Howard counties to the northward, and to the east and west as far as the rocks of this stage are typically developed in Iowa. This uniformly present and easily distinguished horizon will be taken as a convenient standard of reference for the layers of the rocks of the Cedar Valley stage in Benton county.

Near the north line of sections 14 and 15 of Taylor township the flood plain of the Cedar river is bounded on the north by an escarpment fifty to sixty feet in height. The ledges in the face of this bluff are mostly concealed by Kansan drift, but there are occasional outcrops where rocks appear at the surface. At the very top of this scarp the weathered edges of the uppermost layers of limestone appear somewhat interruptedly through the till for a distance of more than one mile.

Mr. Pettit has opened a quarry in the northwest quarter of section 14, near the base of the bluff mentioned above. The rocks at this place are yellowish colored limestone, not greatly disturbed. They contain numerous fossils, among which the following forms are not rare: *Spirifer pennatus*, *Atrypa*

reticularis and very large forms of *Orthis iowensis*, besides fragments of several individuals of a loosely coiled species of Gyroceras. There is exposed at this place a vertical height of about ten feet. The horizon is that of the Gyroceras beds which belong to a zone immediately beneath the beds of *Spirifer pennatus*.

Some rods further west in the same bank there is exposed a ledge about twenty feet in height which occupies a position nearly midway between the base and the top of the bluff. The character of the rocks at this point appears in figure 8. They consist of light gray limestones which are much brecciated

FIG. 8. View of the *Spirifer pennatus* beds at the most westerly exposure in the east bluff of the Cedar river valley, section 15, Taylor township

throughout the thickness of the outcrop. In the lower portion of this exposure, which lies about ten feet above the top of the Pettit quarry section, there occur in abundance, large and robust forms of *Spirifer pennatus*, and numerous individuals of the finely striated-form of *Atrypa reticularis* with widely extending lamellæ, similar to the type that occurs at Independence.

With these fossils are associated *Spirifer bimesialis*, *Gypidula comis* and large shells of *Orthis iowensis*. In the upper half of this exposure *Spirifer pennatus* becomes less abundant, the form of *Atrypa reticularis* becomes more coarsely ribbed, *Orthis iowensis* continues but the individuals are of smaller size. There appear besides the above species numerous individuals of the variety *occidentalis* of *Atrypa aspera*. The rocks exposed at this point belong to the *Spirifer pennatus* horizon which constitutes the uppermost member of the Fayette sub-stage.

About eight rods east of this place there is exposed, near the top of the bluff, a thickness of about thirteen feet of evenly

FIG. 9. Exposure in an abandoned quarry, section 15 of Taylor township. The *Acervularia davidsoni* coral reef appears at the top. The view shows the character of the layers between this coral reef and the zone of *Acervularia profunda*.

bedded, gray limestone, shown in figure 9. At the very top of this bed there is a layer about two feet in depth composed almost wholly of coral remains. Prominent among these are beautiful colonies of *Acervularia davidsoni*, *Favosites alpenensis*, numerous

individuals of Favosites sp. *Cystiphyllum americanum*, *Heliophyllum halli*, *Ptychophyllum versiforme*, besides an undetermined species of Cyathophyllum and of Stromatopora. At the top of this layer the coralla are weathered free from the limestone matrix and are much iron-stained, indicating that the reef may originally have been thicker than at present. The upper portion of this bed doubtless suffered degradation through the agencies of weathering before it was covered by the protecting mantle of drift.

Below the coral reef the limestone is in regular layers which vary from a few inches to two or three feet in thickness. The fossils, *Spirifer parryanus* and *Cladopora iowensis* occur immediately below the reef, while *Orthis iowensis*, *Atrypa reticularis* and the varieties of *Atrypa aspera* are abundant in the layers in the lower part of the exposure.

The layers that can be seen at this place correspond with numbers 4 to 8 inclusive of the section of Quinn's quarry. They are all slightly flexed, but they were not involved in the brecciation and disturbance that so profoundly affected the underlying beds which outcrop a few rods west of this place.

From these exposures it is evident that the layers of limestone through which the waters of the Cedar river have cut during the course of development of this portion of its channel are embraced between the *Acervularia davidsoni* coral reef at the top, and the Gyroceras beds at the base. These layers include the lower representatives of the rocks of the Cedar Valley stage and the uppermost members of those of the Wapsipinicon. All of the rocks exposed in Taylor township adjacent to the town of Vinton, as well as the most of those which outcrop further eastward, in the vicinity of Shellsburg, find their equivalent in some portion of the beds embraced between the two members mentioned above.

Near the northwest corner of section 22, Taylor township, in the corporate limits of the town of Vinton, Mr. Rosenberger has opened a quarry which is at present operated by the city. At this place the following section was observed below the surface materials:

		FEET.
3.	Bed of light colored limestone, in rather regular layers a few inches to one foot in thickness. These layers contain *Orthis iowensis*, *Atrypa reticularis*, *Atrypa aspera* vars. *hystrix* and *occidentalis*	6
2	Layer of gray limestone in which coralla of *Acervularia profunda*, an undetermined species of Cystiphyllum and a spherical form of Favosites are not infrequent	1
1.	Bed of light gray limestone, much shattered and brecciated, in some places showing indistinct planes of bedding; containing the fossils; *Spirifer pennatus*, *Gypidula comis*, *Gypidula læviuscula*, *Atrypa reticularis*, *Atrypa aspera* var., *Pentamerella arata*, *Dielasma iowensis* and *D. romingeri*, besides a gastropod resembling a species of Pleurotomaria	14

In this section number 1 corresponds with the shattered zone described as the *Spirifer pennatus* beds at the most westerly exposure in the Cedar river bluff, in Taylor township. It is the equivalent of number 2 of the Quinn quarry section. The rocks of this horizon are usually more or less shattered or disturbed wherever in the county they are exposed. Number 2 above is the equivalent of number 3 in the Quinn quarry exposure. The presence of *Acervularia profunda* in this member makes it an easily recognized zone immediately overlying the beds of *Spirifer pennatus*. Number 3 of the Rosenberger section is the correlative of number 6 in the section of Quinn's quarry.

In the extreme eastern portion of the county there are exposed rocks which introduce a horizon a little higher than those at the Rosenberger quarry. The following section was made a short distance southeast of Shellsburg, on land owned by Mr. Dwigan. The quarry is in the south bank of Bear creek, near the middle of section 14 of Canton township:

		FEET.
9.	Dark gray soil, without pebbles or bowlders	1½
8.	Reddish-brown clay containing numerous pebbles of trap and quartz, and occasional bowlders of granite	2
7.	Ledge made up of layers of much decayed, gray limestone through which numerous water passages have been formed by solution and erosion.	3

		FEET.
6.	Layer crowded with coral remains, among which coralla of *Acervularia davidsoni* are predominant. *Favosites alpenensis*, Favosites sp., *Cystiphyllum americanum* and *Ptychophyllum versiforme* also are not rare	2½
5.	Layer of light gray limestone which weathers into thin chips, and contains *Spirifer parryanus* and *Cladopora iowensis*	1½
4.	Ledge of hard, brachiopod limestone, gray in color, in some places forming a single layer and in others showing an indefinite line of separation into two parts. Fragments of the fossils *Orthis iowensis* and *Atrypa reticularis* are very abundant	4
3.	Bed composed of two layers, each about twenty inches in thickness. This limestone is dark-gray in color and contains numerous remains of *Atrypa reticularis*, *Atrypa aspera* var., *Orthis iowensis*, *Spirifer pennatus*, *Cladopora iowensis* and a species of Cyathophyllum	3½
2.	Layer of shelly, gray limestone, similar in color and texture to number 3 above, and containing similar fossils	1
1.	Bed composed of three layers of limestone, respectively 1½ and 2 feet in thickness. These layers carry the following fossils: *Spirifer pennatus*, *Atrypa reticularis*, *Atrypa aspera* var., *Orthis iowensis*, *Stropheodonta demissa* and, in the lowermost layer, coralla of *Acervularia profunda*, and of a species of Cyathophyllum and of Favosites	4½

In the above, which will be referred to as the Dwigan quarry section, numbers 1 to 5 inclusive represent the successive layers of limestone that normally intervene between the *Acervularia davidsoni* coral reef and the zone of *Acervularia profunda*. *Spirifer parryanus* occupies a definite position in the layer immediately below the main coral reef. *Cladopora iowensis* Owen (*Striatopora rugosa* Hall) is generally associated with *Spirifer parryanus*, but it is also abundant throughout the layers for a depth of five or six feet below the zone of that Spirifer. Number 6 represents the coral reef of the *Acervularia davidsoni* horizon. Its development here and its coral content are consistent with that of the *Acervularia davidsoni* reef at this particular well marked horizon at other points in the state. It is the equivalent of number 8 of the Quinn quarry section,

and corresponds with the uppermost layer that appears in the north bluff of the Cedar river valley, in sections 14 and 15 of Taylor township.

Number 8 is a bed of Kansan drift so shallow that the atmosphere has more or less completely effected the oxidation of its iron content throughout the entire depth. Number 9 is a dark colored soil that has been formed upon the surface of the till. It is rarely that the drift is exposed at the surface in Benton county except upon hillslopes where the fine-grained overlying material has been removed by erosion. This homogenous deposit is probably a wind blown substance that was laid down above the drift in a manner similar to that of the loess in this portion of the state. The dark color of the soil band is due to the accumulation of carbonaceous matter which has resulted from the decay of countless generations of plants during the centuries through which vegetation has flourished upon the present surface.

About one mile east and seven miles north of Dwigan's quarry, there is exposed a vertical escarpment of limestone forty-two feet in height. In this cliff, which is known locally as Wild Cat bluff, there are presented layers of the Cedar Valley limestone which lie above any of the beds that outcrop around Shellsburg or in the immediate vicinity of Vinton. The ledge is on land owned by Mr. Broaddy, and is located near the middle of section 10 of the congressional township of Benton. It forms the north bank of the Cedar river about twenty rods west of the wagon bridge across that stream. At this place the following section is exposed:

	FEET.
12. Homogeneous, fine-grained material, dark gray in color throughout the greater portion of its depth. This pebbleless soil has slipped down from above, concealing the face of the bed of drift that normally underlies the soil band....	4
11. Bed of impure, yellowish-brown limestone which weathers into layers four to eight inches in thickness. Between the layers are frequently intercalated narrow bands of chert nodules and quartz geodes. This bed contains disks of crinoid stems, besides the shells of *Spirifer subvaricosus*, a large Spirifer resembling *S pennatus* and, in its lower portion, the very large, coarse-ribbed variety of *Atrypa reticularis*...	6

		FEET.
10.	Bed of yellowish, impure limestone which weathers into thin, fissile fragments and carries the fossils *Stropheodonta demissa*, *Orthis iowensis*, *Atrypa reticularis*, the large Spirifer somewhat resembling *S. pennatus* and a species of coral belonging to the genus Cyathophyllum	5
9.	Bed of hard, gray limestone which weathers into layers two or three inches to one foot in thickness, and contains fossils similar to those found in number 10 above..................	3½
8.	Layer crowded with coralla of *Acervularia davidsoni*, *Favosites alpenensis*, and the other corals usually associated with these in the main coral reef..	2
7.	Layer of hard, gray limestone, containing numerous fragments of crinoid stems together with the fossils *Spirifer parryanus*, *Orthis iowensis*, *Atrypa reticularis*, *Cladopora iowensis*, *Acervularia davidsoni* and an undetermined species of Favosites................	1½
6.	Bed made up of three layers of gray limestone, each about sixteen inches in thickness, containing *Cladopora iowensis*, *Orthis iowensis*, *Atrypa reticularis* and a Spirifer much like *S. pennatus*..................	4
5.	Bed of gray limestone composed of four layers, respectively six, seven, eight and twelve inches in thickness; carrying fossils similar to those found in number 6, together with *Atrypa aspera* var. *occidentalis*......................	2½
4.	Bed of white limestone, in three imperfect layers each about four inches in thickness; containing fossils similar to those found in number 5, besides fragments of bryozoans and shells of *Orthothetes chemungensis*......	1
3.	Ledge of gray limestone, containing in abundance the fossils *Orthis iowensis*, *Atrypa reticularis*, *A. aspera* var. and *Spirifer pennatus*...	4½
2.	Massive layer of dark gray limestone, composed of coarse fragments of brachiopod shells among which those found in number 3 above are predominant; with these are associated undetermined species of corals belonging to the genera Favosites and Cyathophyllum....	5½
1.	Bed of light gray limestone, less rich in fossils than the overlying layers; containing *Spirifer pennatus*, *Orthis iowensis*, *Atrypa aspera* var. *occidentalis*, *A. reticularis* and a species of Cyathophyllum.............................	6½

In the above section, which may be referred to as that of the Wild Cat bluff, number 1 probably corresponds with the upper portion of the *Spirifer pennatus* beds. Although there is no brecciation or disturbance in the rocks of this member, yet the fossils occurring here are not inconsistent with those found near the top of the Wapsipinicon stage. The relation which this bed sustains to the overlying coral-bearing zone would also indicate its position at the upper part of the *Spirifer pennatus* horizon. This member is the equivalent of number 2 of the Quinn quarry section, and corresponds with the upper part of number 1 of Rosenberger's quarry. At Wild Cat bluff the bank below number 1 is talus covered for a distance of twenty-two feet, down to the water's edge. Number 2 probably represents the zone of *Acervularia profunda.* Although no coralla of *Acervularia profunda* were found at this exposure, corals usually associated with that fossil are abundant in number 2. This member is easily correlated with number 3 of the Quinn quarry section, with number 2 of the Rosenberger quarry, and with number 1 of the section at Dwigan's quarry, near Shellsburg.

The *Acervularia profunda* zone is quite constant in Benton county at a horizon about twelve feet below that of the *A. davidsoni* reef, but in the exposure at Wild Cat bluff there is present a thickness of about nineteen feet of Cedar Valley limestone below the reef of *Acervularia davidsoni.* In Taylor township the position of this coral reef is only about thirteen feet above the base of the Cedar Valley stage. In Buchanan county, farther north, a still less vertical distance separates the *Spirifer pennatus* beds from the coral reef, while to the southward, in Johnson county, a thickness of forty-eight feet of limestone intervenes between the *Acervularia davidsoni* horizon and the base of the Cedar Valley stage. The members 3 to 6 inclusive, at this place, resemble the rocks seen at the corresponding horizon at other points in Benton county. The material is quite hard, and occurs in rather regular layers. It is largely composed of more or less perfectly comminuted fragments of brachiopod shells. The assemblage of fossils which characterize these layers includes very numerous individuals of

Atrypa aspera var. *occidentalis* associated with which are *Atrypa reticularis*, *Orthis iowensis* and *Spirifer pennatus*. While the fossil *Spirifer pennatus* is quite uniformly present in these members it does not occur here in such abundance as it does lower down in the proper *Spirifer pennatus* zone. At this higher horizon, too, the cardino-lateral margins of the shells of this species are usually prolonged into relatively wide extensions. Number 4 contains fragments of the shells of *Orthothetes chemungensis;* and in number 6 the coral *Cladopora iowensis* is abundant. The shells of *Orthis iowensis* found in these layers are very much smaller and less flaring than those of the individuals of this species in numbers 1 and 2 of this same section.

Number 7 represents the typical development of the layer which immediately underlies the *Acervularia davidsoni* coral reef. The diagnostic fossil of this layer is *Spirifer parryanus*. Associated with this species there also occur *Cladopora iowensis*, *Orthis iowensis*, *Atrypa reticularis*, occasional coralla of *Acervularia davidsoni* and of a spherical species of Favosites, the latter corals being introduced a short distance below the coral reef proper. Number 8 represents the *Acervularia davidsoni* reef with its usual assemblage of corals. Many of the coralla at this place have weathered out of the soft, shaly matrix so that exceptionally perfect and beautiful specimens are exposed.

In the absence of any contrary indications Professor Geikie* assumes that these Paleozoic limestone building corals, like their modern representatives, flourished only in the seas where the minimum temperature never fell below 68° Fahr. If this assumption be true, the constant and uniform development of the coral zones of the Devonian system in Benton county, and in our state, would testify to the prevalence of a much more genial and uniform temperature in our latitude during the ages of the Devonian through which these deposits were being formed. That these ancient corals, like their present relatives, flourished best in seas where the waters were contaminated by no mechanical sediments is indicated by the fact that in the coral zones like the *Acervularia davidsoni* reef the coralla

*Geikie: Text Book of Geology, 4th Ed., 1903, p. 943.

form a compact layer. The interstices only are occupied by calcareous, shaly material which may readily have been derived from the coral masses by the attrition incident upon the action of the waves before the materials became consolidated.

It seems certain that the growth of the Devonian corals was restricted by some special conditions of existence from the abruptness with which the reef species give place to other fossils in the layers immediately above and below the narrow coral horizon.

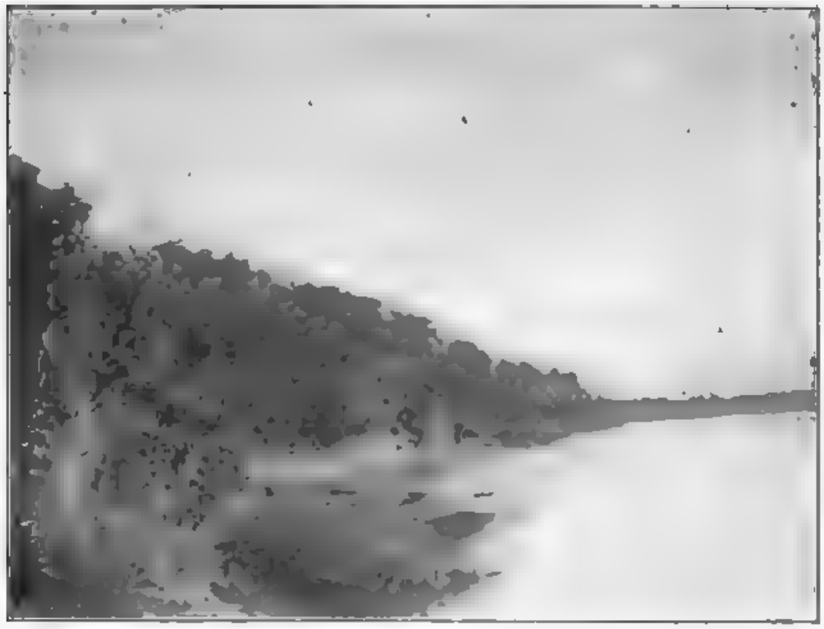

FIG. 10. Exposure of Cedar Valley limestone in the east bank of the Cedar river, a short distance south of Long's quarry, Harrison township.

Numbers 10 and 11 of the last section are composed of impure, earthy limestone, yellow in color and rather fine-grained in texture. They contain numerous nodules of chert which are often arranged in more or less definite bands. Geodes of quartz are also abundant in these beds. The characteristic fossil of number 11 is the very large, coarse-ribbed variety of *Atrypa reticularis*. The shells of this species are here three inches in length and about as wide as long. The surface is

marked by very coarse striae as compared with the ornamentation of the forms of normal size. The constant occurrence in this zone of such a remarkable form of *Atrypa reticularis* renders the identification and correlation of this member an easy task. It marks a definite horizon about nine feet above that of the *Acervularia davidsoni* reef in the deposits near the middle portion of the Cedar Valley stage. In numbers 10 and 11 there also occur shells of a large Spirifer which resembles in some respects *S. pennatus*, *Spirifer subvaricosus*, and large forms of *Stropheodonta demissa* which are considerably wider than long.

Near the northwest corner of section 9, Harrison township, the Cedar river sweeps with a broad curve to the southward. At this place the force of the current has been directed against the bank which bounds the valley on the east. The river here is bordered for several rods by a ledge of limestone fifty feet in height. See figure 10. This exposure below the drift affords an exceedingly instructive section which is given below:

	FEET.
10. Bed of fine-grained, impure limestone, yellowish in color, made up of regular layers from three to twelve inches in thickness, which carry but few fossils, but contain abundant small concretions of chert..................	13
9. Bed of dense, gray, fine-grained limestone which is crowded with detached shells of a large Spirifer and *Camarotœchia* cf. *prolifica*. Occasional shells of *Atrypa reticularis* and *Cyrtina hamiltonensis* are also present.........	½
8. Bed of impure, magnesian limestone, in layers from two to twenty inches in thickness, yellowish-brown in color, and carrying but few fossils. Nodules of chert are abundant in this member...........................	10
7. Bed of limestone, variable in color, separable into a number of indefinite layers, yielding but slowly to the action of the atmosphere; containing the fossils, Favosites sp., Rynchonella sp., Spirifer sp., and teeth of *Ptyctodus calceolus*. Near the top occurs the very large, coarse-ribbed form of *Atrypa reticularis*...............................	7½

	FEET.
6. Reef composed largely of coralla of *Acervularia davidsoni*, containing also the species of Cyathophyllum, Ptychophyllum, Cystiphyllum and Favosites that usually occur in this zone	3½
5. Layer of gray limestone which contains *Cladopora iowensis*, Favosites sp., *Orthis iowensis*, *Atrypa reticularis*, *Productella subalata*, *Pentamerella dubia*, *Spirifer parryanus* and very large tritors of *Ptyctodus calceolus*.....	4
4. Bed made up of two layers of hard, shelly limestone, respectively sixteen and twelve inches in thickness. This bed carries the fossils found in number 3 below, together with *Cladopora iowensis*, Cyathophyllum sp., six-rayed spicules of sponge, four different species of bryozoa, *Stropheodonta demissa* and a species of Orthothetes........	2½
3. Layer of gray limestone, almost a brachiopod coquina, in which there occurs in abundance the remains of *Spirifer pennatus*, *Atrypa aspera* var. *occidentalis*, *Atrypa reticularis* and *Orthis iowensis*......................	3
2. Regular layers of rather hard, gray limestone, not broken or disturbed, and bearing numerous fossils, among which are *Acervularia profunda*, Favosites sp., Cyathophyllum sp., Cladopora sp., Stromatopora sp., *Stropheodonta demissa*, *Orthis iowensis*, *Atrypa reticularis*, the var. *occidentalis* of *Atrypa aspera*, *Productella subalata*, Chonetes sp. and a thin shell belonging to the genus Dielasma..................................	2
1. Bed of light gray limestone, somewhat shattered and brecciated, containing the fossils *Stropheodonta demissa*, *Orthis iowensis*, *Atrypa reticularis*, *Atrypa aspera* var. *occidentalis*, *Spirifer pennatus* and a species of Gomphoceras, exposed to the water's edge	3

In the above, which may be designated as the Cedar River section, number 1 represents the gray, brecciated limestone near the upper part of the *Spirifer pennatus* beds. It is the equivalent of the upper portion of number 1 of the Bliss quarry section, and corresponds with the upper part of number 1 at the Rosenberger quarry. The fossil *Gypidula comis*, which is charteristic of this zone, was not found at the Cedar River exposure.

However, the limited area of the rocks here exposed makes it possible that it may be present at this place, although not detected. The rocks are thoroughly shattered and much displaced in a manner typical of the Fayette breccia horizon.

Number 2 is the *Acervularia profunda* bed which constitutes the basal member of the Cedar Valley stage in Benton county. The elegant coral, *Phillipsastrea billingsi* Calvin, whose large and beautiful colonies are often associated with *Acervularia profunda* at this horizon in Buchanan county, was not seen at any point in the county of Benton. This member is easily correlated with number 3 of the Quinn quarry section, with number 2 of the Rosenberger quarry, and with number 2 of the exposure at Wild Cat bluff.

The members 3 to 5 inclusive, of this section, contain the typical fossils and represent the normal development of the limestones that intervene between the *Acervularia profunda* zone and the *Acervularia davidsoni* coral reef. They find their ready correlative in the beds that lie between those two horizons at all points in the county where these rocks are exposed. Number 6 is the *Acervularia davidsoni* reef which is universally present at this horizon in this county, and in the most of the other counties of eastern Iowa that are crossed by the Cedar river.

Number 7 embraces the bed of variable limestone that, for a few feet in height, normally overlies the coral reef. The presence of the very large, coarsely-striated type of *Atrypa reticularis*, which occupies a position near the top of the bed, makes it possible to assign this member to its proper place in the series of the Cedar Valley limestones, even where the well marked reef which underlies it is not exposed. The upper portion of this member is the equivalent of the lower portion of number 11 in the Wild Cat bluff exposure. The layers that lie between the zone containing the large, coarse form of *Atrypa reticularis* and the coral reef are quite variable in their development. The sediments of which they are formed were probably laid down at no great distance from shore, on a sea bottom where the wave action was vigorous, at times, but more or less inconstant. Shells of a large species of Spirifer are frequently

found associated with the large type of *Atrypa reticularis* in the exposures in Benton county.

The layers included in number 8 are evenly bedded, impure limestones which are yellowish in color, fine-grained in texture and contain but few fossils. In the quarries that are opened along the Cedar river in the northern portion of the county, the equivalent of the layers in number 8, and the beds which overlie that member, furnish the best stone that the county affords, with the exception of the limited amount of the Coggan limestone described above.

The thicker layers of this member were originally of a blue color. In some of these the change to yellow has been accomplished only for a thickness of three or four inches adjacent to the planes of bedding, leaving a narrow band of unchanged blue color in the middle portion. The materials of these beds are quite hard and the natural ledges show a good degree of resistance to the disintegrating agencies of the atmosphere where they have been long exposed to the weather.

Number 9 is a narrow layer of very hard, fine-grained limestone. It is gray in color and contains in great abundance a large, undescribed species of Spirifer. With this species were associated *Cyrtina hamiltonensis*, Camarotœchia cf. *C. prolifica* and a small form of *Atrypa reticularis*. This narrow band is quite constant in its lithology and fossil content over all of the northern portion of Benton county. It furnishes a valuable means of correlation, and marks a definite horizon about ten feet above the zone of the very large, coarse type of *Atrypa reticularis.*

Number 10 is made up of a number of layers of dense, fine-grained limestone of variable thickness. In some of the exposures the layers are composed of yellow, magnesian materials, while at other points not far distant they are light gray, almost pure, limestones without any trace of the magnesian character. Chert nodules are abundant in this bed. Sometimes they are segregated along the planes of stratification so as to form a narrow band, and again they are scattered indiscriminately through the materials of the different layers. At this place the

	FEET.
4. Bed of light gray limestone, in layers from three to nine inches in thickness. In some cases partings of soft, gray shale separate adjacent layers. The material is fine-grained, and contains numerous concretions of chert and but few fossils	9
3. Layer composed almost wholly of chert nodules which vary from two to three inches to over one foot in long diameter	⅔
2. Bed of gray limestone which weathers into a number of rather indistinct layers, two to eight inches in thickness; containing *Stropheodonta demissa*, Spirifer sp., and the very robust, coarsely-striated variety of *Atrypa reticularis*	3
1. Ledge of hard, gray limestone which weathers into thin bits, and contains a large species of Spirifer	2

In the above section the presence of the very large form of *Atrypa reticularis* in the second member determines that horizon as the equivalent of the upper portion of number 7 of the Cedar River section, and of the lower portion of number 11 of the Wild Cat bluff exposure. With respect to number 2 the other members of the section are readily assigned their proper places in the Cedar Valley series. The position of number 1 is about three or four feet above the *Acervularia davidsoni* reef, while numbers 3 and 4 inclusive correspond with number 8 of the Cedar River section.

Some rods to the north of Knapp's quarry, near the north end of the same lake, Mr. McKinley has taken out stone from layers which correspond with number 4 of the Knapp quarry section. In both of these exposures the rocks which belong to the horizon of number 4 above are fine-grained, gray limestones which contain no fossils. Chert nodules are abundant in these beds, as they are in the corresponding layers of the Cedar River and the Long quarry exposures. At McKinley's quarry, too, the layers dip to the south at about the same angle as those described in the Cedar River section.

Directly across the river, and about one-half mile west, from McKinley's quarry the water of the Cedar washes the foot of a ledge of limestone twenty-five feet in height. This bluff is on

an undescribed species of Spirifer and a Camarotœchia resembling *C. prolifica.* This layer is the equivalent of number 9 of the Cedar River section.

Intervening between the horizon of the coarse Atrypa and the narrow zone containing Camarotœchia and Spirifer sp., there occurs about ten feet of regularly bedded, yellow limestone which is the equivalent of the layers constituting number 8 of the Cedar River exposure. The materials of these layers at Long's quarry are fine-grained, impure limestone, containing numerous chert concretions. In cross section the thinner layers are yellow in color throughout, as are also the thicker ones with the exception of a narrow band of blue in the middle portion. It is probable that all of these layers were originally a blue stone, and that they have been changed to a yellow color through the action of the chemical agencies of the atmosphere and of percolating waters. The stone from this bed is of durable quality. It occurs in layers of such thickness as to be conveniently worked, and it can be quarried in blocks of almost any size desired. Some of the material in the abutments of the bridge that spans the Cedar river near the north line of the county came from the layers of number 8 at Long's quarry. At this place the narrow, Camarotœchia zone is succeeded by a bed of limestone about twelve feet in thickness, which is the equivalent of number 10 of the last section presented. The rocks of this uppermost bed resemble those of the corresponding horizon in the Cedar River section in the thickness of the layers, in the color and texture of the materials, in the abundance of chert nodules, and in the scarcity of fossils.

About two miles south of the Cedar River exposure Mr. George Knapp has opened a quarry in the bank which borders Minnie Estima lake on the east. This lake is a lagoon or ox-bow cut-off lying in the flood plain of the Cedar river, in section 16 of Harrison township. At this place the following layers are exposed below the drift:

		FEET.
4.	Bed of light gray limestone, in layers from three to nine inches in thickness. In some cases partings of soft, gray shale separate adjacent layers. The material is fine-grained, and contains numerous concretions of chert and but few fossils..................................	9
3.	Layer composed almost wholly of chert nodules which vary from two to three inches to over one foot in long diameter.........................	⅔
2.	Bed of gray limestone which weathers into a number of rather indistinct layers, two to eight inches in thickness; containing *Stropheodonta demissa*, Spirifer sp., and the very robust, coarsely-striated variety of *Atrypa reticularis*..	3
1.	Ledge of hard, gray limestone which weathers into thin bits, and contains a large species of Spirifer	2

In the above section the presence of the very large form of *Atrypa reticularis* in the second member determines that horizon as the equivalent of the upper portion of number 7 of the Cedar River section, and of the lower portion of number 11 of the Wild Cat bluff exposure. With respect to number 2 the other members of the section are readily assigned their proper places in the Cedar Valley series. The position of number 1 is about three or four feet above the *Acervularia davidsoni* reef, while numbers 3 and 4 inclusive correspond with number 8 of the Cedar River section.

Some rods to the north of Knapp's quarry, near the north end of the same lake, Mr. McKinley has taken out stone from layers which correspond with number 4 of the Knapp quarry section. In both of these exposures the rocks which belong to the horizon of number 4 above are fine-grained, gray limestones which contain no fossils. Chert nodules are abundant in these beds, as they are in the corresponding layers of the Cedar River and the Long quarry exposures. At McKinley's quarry, too, the layers dip to the south at about the same angle as those described in the Cedar River section.

Directly across the river, and about one-half mile west, from McKinley's quarry the water of the Cedar washes the foot of a ledge of limestone twenty-five feet in height. This bluff is on

	FEET.
3. Yellowish-brown layer of fine-grained, impure limestone; carrying occasional concretions of chert which are most numerous adjacent to the planes of bedding	2½
2. Layer of variable, impure limestone, fine-grained and very hard. Near the base of this layer chert nodules are abundant, and shells of a large form of Spirifer and *Camarotœchia* cf. *prolifica* are very numerous	2
1. Bed made up of two layers of buff, earthy limestone in which, at irregular intervals, occur bands and numerous masses of chert, without fossils; to base of the exposure which is about four feet above the level of the water	4

The layers in this quarry are cut by numerous, oblique joints which divide the ledge into large rhombic masses. The material of which the beds are composed is mostly a fine-grained, earthy limestone. Many of the layers are strongly magnesian, and some of them are so thoroughly dolomitic that they respond but slightly to the application of cold hydrochloric acid. The entire ledge is regularly bedded, and furnishes quarry stone of convenient dimensions and durable quality.

In the section of Keiser's quarry, number 2, the only member that contains fossils, furnishes the key to the correlation of the beds. From the identity of their fossil contents the lower portion of number 2 is considered the equivalent of the upper portion of number 2 of the Kirkland quarry section, and it corresponds with number 9 in the Cedar River exposure. The numbers 3 to 10 inclusive of the Keiser section are the equivalent of the beds embraced by the numbers 3 to 9 of that at the Kirkland quarry. They are also the correlative of number 10 of the Cedar River section. Number 1 of the Keiser quarry section corresponds with number 1 of Kirkland's quarry, and with the upper portion of number 8 of the Cedar River section.

Still further north, in Buchanan county, the materials which compose the rocks of this horizon preserve the yellow color and the earthy, magnesian character that distinguish them in the northern portion of Benton.

The most westerly exposure of indurated rocks in Benton county, as far as is known, is on land owned by Mr. John Tripp,

of the layers constituting number 10 in the Cedar River section. Number 9 above probably represents a zone higher in the Cedar Valley series than any previously noted in the county. Number 1, together with the major portion of number 2 in the Kirkland section, corresponds with the upper portion of number 8 of the Cedar River section, with the upper portion of the Knapp and McKinley quarry sections, and with the upper part of number 11 of the Wild Cat bluff exposure. The development of the members represented in the Kirkland section is not much different from that in the exposures on the east side of the river. The beds of this horizon become more yellow in color, and carry a much larger proportion of earthy impurities further to the northward, as is seen at Long's quarry and in the Cedar River section given above. This fact is also strikingly shown in an exposure in the west bank of the Cedar river near the north line of Benton county.

This ledge is a short distance below the river bridge, near the northwest corner of section 6 of Harrison township. The quarry is owned by Mr. Keiser, and presents the following succession of layers:

		FEET.
12.	Dark colored, fine-grained, pebbleless soil	1
11.	Bed of reddish-brown clay, containing numerous pebbles of quartz and greenstone with occasional granite bowlders of larger size	2
10	Layer of much decayed fragments of brown limestone, without fossils	3
9.	Bed composed of two layers of yellow, earthy limestone, each about eight inches in thickness, fine-grained and without fossils	1⅓
8.	Bed of gray limestone which weathers into thin layers about one inch in thickness, without fossils	3
7.	Layer of very hard, earthy limestone, yellow in color and fine-grained in texture; fossils wanting	⅚
6.	Bed made up of layers of buff, earthy limestone two to six inches in thickness, which are fine-grained in texture and non-fossiliferous	3⅓
5.	Layer of yellow, impure limestone which weathers into indistinct layers three to six inches in thickness; without fossils	1⅓
4.	Layer similar to number 5 above	2

	FEET.
3. Yellowish-brown layer of fine-grained, impure limestone; carrying occasional concretions of chert which are most numerous adjacent to the planes of bedding	2½
2. Layer of variable, impure limestone, fine-grained and very hard. Near the base of this layer chert nodules are abundant, and shells of a large form of Spirifer and *Camarotœchia* cf. *prolifica* are very numerous	2
1. Bed made up of two layers of buff, earthy limestone in which, at irregular intervals, occur bands and numerous masses of chert, without fossils; to base of the exposure which is about four feet above the level of the water	4

The layers in this quarry are cut by numerous, oblique joints which divide the ledge into large rhombic masses. The material of which the beds are composed is mostly a fine-grained, earthy limestone. Many of the layers are strongly magnesian, and some of them are so thoroughly dolomitic that they respond but slightly to the application of cold hydrochloric acid. The entire ledge is regularly bedded, and furnishes quarry stone of convenient dimensions and durable quality.

In the section of Keiser's quarry, number 2, the only member that contains fossils, furnishes the key to the correlation of the beds. From the identity of their fossil contents the lower portion of number 2 is considered the equivalent of the upper portion of number 2 of the Kirkland quarry section, and it corresponds with number 9 in the Cedar River exposure. The numbers 3 to 10 inclusive of the Keiser section are the equivalent of the beds embraced by the numbers 3 to 9 of that at the Kirkland quarry. They are also the correlative of number 10 of the Cedar River section. Number 1 of the Keiser quarry section corresponds with number 1 of Kirkland's quarry, and with the upper portion of number 8 of the Cedar River section.

Still further north, in Buchanan county, the materials which compose the rocks of this horizon preserve the yellow color and the earthy, magnesian character that distinguish them in the northern portion of Benton.

The most westerly exposure of indurated rocks in Benton county, as far as is known, is on land owned by Mr. John Tripp,

near the northwest corner of section 17 of Cedar township. This quarry is opened on the south side of the wagon road along the east bank of Rock creek. At this place, too, the beds are cut by very numerous joints, and they are inclined strongly towards the south.

The section exposed below the superficial materials is as follows:

	FEET.
4. Bed of yellow, earthy limestone, fine-grained and without fossils, made up of irregular layers which are not continuous throughout the few rods in length of the exposure	6
3. Bed of buff, fine-grained, magnesian limestone, composed of layers four to eight inches in thickness, without fossils	3
2. Layer of impure, yellow limestone which is fine-grained, and contains fragments of several fossils in a poor state of preservation	1½
1. Bed of buff colored dolomite, made up of two layers, each about eighteen inches in thickness; without fossils	3

In this quarry the rock is more or less perfectly dolomitic throughout. It is fine-grained, subcrystalline in texture, and is uniformly of a deep yellow color. The lithology of these layers is unlike that of any beds seen elsewhere in the county. Number 2 of the section contains fragments of the following fossils which furnish the only means of assigning the layers to their proper place in the deposits of the Cedar Valley stage:

Cladopora iowensis Owen.
Favosites sp.
Cyathophyllum sp.
Cystiphyllum sp.
Stropheodonta demissa Conrad. Large, broad forms.
Atrypa reticularis Linn. Coarse forms, but not so robust as the largest type.
Spirifer sp. Large individuals.
Ptyctodus calceolus Newberry and Worthen. Large tritors three inches in length; also concave teeth, and large fish plates, 6x2 inches.

None of the above fossils are diagnostic of a definite zone. *Cladopora iowensis* occurs most abundantly immediately above, or a short distance below, the *Acervularia davidsoni* coral reef. This form of Spirifer is not infrequently found at the same horizons in Benton county. *Atrypa reticularis* also occurs both above and below the above mentioned reef, but when found below the reef it is almost invariably accompanied by *Orthis iowensis*, which latter fossil did not appear at Tripp's quarry. At this place, too, the *Atrypa reticularis* was larger and more

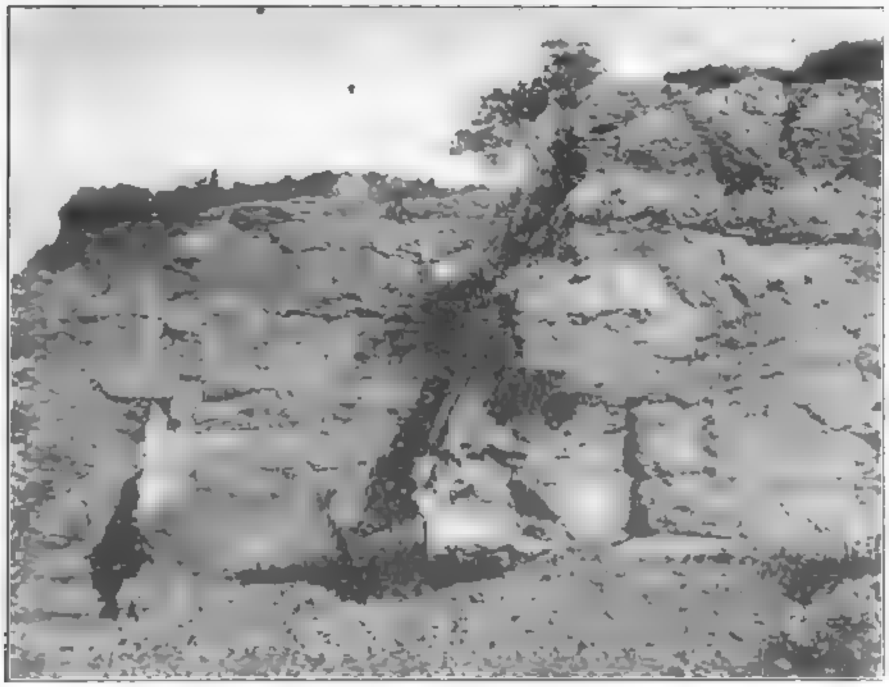

FIG. 12. Exposure in the abandoned quarry on Hinkle creek, near Garrison. The Stromatopora reef appears near the top. The rocks here represent the uppermost layers of Cedar Valley limestone found in Benton county.

strongly marked than the form normally occurring below the coral reef, although it was not so robust and coarsely-ribbed as the typical form at the horizon about eight feet above that zone. The large, broad form of *Stropheodonta demissa* normally occurs a short distance above the coral reef, while occasional

coralla of the other corals found in this member might be encountered either above or below the *Acervularia davidsoni* horizon. If the position of these rocks was immediately below the coral reef, they would probably contain the fossil *Spirifer parryanus*. If they represent a zone some distance below the reef they would almost certainly contain *Atrypa aspera* var. *occidentalis* and *Orthis iowensis*.

From the above considerations it seems probable that the rocks exposed at Tripp's quarry represent a dolomitic phase of the Cedar Valley limestones belonging to a horizon not far above the *Acervularia davidsoni* coral reef. Number 2 in the section would then be the equivalent of number 2 of the Knapp quarry section, and would correspond with the upper portion of number 7 of the Cedar River section, and with the lower portion of number 11 of the Wild Cat bluff exposure.

An exceedingly interesting rock exposure occurs about nine miles south and two miles east of John Tripp's quarry. This outcrop is near the southeast corner of section 28 of Jackson township, about one-half mile east of the town of Garrison. See figure 12. At this place stone was formerly quarried in large quantities for the Burlington, Cedar Rapids and Northern railroad. The ledge was worked in the south bank of Hinkle creek, just south of the track and east of the railroad bridge across that stream. A section at this abandoned quarry shows the following succession of layers:

		FEET.
10.	Fine-grained, pebbleless material, dark gray in color at the top, grading down to yellow in the middle and lower portions	3
9.	Bed of reddish-brown clay, containing numerous pebbles and occasional bowlders	2
8.	Ledge of light gray, subcrystalline limestone, very hard and somewhat brecciated, containing numerous spherical Stromatoporoids	3
7.	Massive ledge of dense, gray limestone, composed largely of various species of Stromatoporoids and masses of Idiostroma-like stems, few of which can be recognized. This bed is also somewhat brecciated in places; and contains fragments of *Dielasma iowensis*, *Gypidula laeviuscula* and casts of *Straparollus cyclostomus*	6

	FEET.
6. Ledge of hard, gray limestone which weathers into two indistinct layers, and contains masses of spherical Stromatoporoids..................	3½
5. Bed of very hard, white, subcrystalline limestone, without fossils..........................	1½
4. Ledge of yellowish-gray, non-fossiliferous limestone which is fine-grained and very hard. The upper portion bears numerous small cavities, the largest of which are nearly one inch in diameter....................................	4
3. Bed of dense, gray limestone, fine-grained and very resistant to weathering; without fossils....	3½
2. Bed composed of several layers of very hard, fine-grained limestone, white in color and without fossils. The layers are six to fifteen inches in thickness....................................	5½
1. Bed made up of two layers of yellowish-brown limestone which are respectively two feet and one and one-half feet in thickness. The material is fine-grained, and contains no fossils.....	3½

The above will be designated as the Garrison section. It seems probable that all of the layers that are encountered in this quarry lie above the zone of the uppermost layers that are exposed in the quarries in the northern portion of the county. Numbers 6 to 8 inclusive are the only members of the Garrison section that contain fossils. In these layers were found numerous masses of spherical Stromatoporoids, and indistinct, branching structures which resemble stems of Idiostroma, together with casts of the gastropod, *Straparollus cyclostomus.*

In the upper portion of the deposits of the Cedar Valley stage, in Johnson county, there occur layers whose lithological characters resemble those of the members 6 to 8 inclusive of the above section, and which carry similar fossils in great abundance. It seems probable that the beds embraced in the numbers 6, 7 and 8 of the Garrison section correspond with those of the above mentioned horizon in Johnson county, and that these layers in the Garrison exposure represent the uppermost series of the Cedar Valley limestone, as the deposits of that age are developed in the county of Benton as well as in Johnson.

The materials of which these members are largely composed are light colored, very hard and exceedingly fine-grained. The brecciated or fractured portion consists of sharply angular frag-

ments of this fine-grained material, from one-half inch to two inches in length, which are firmly cemented together by an interstitial deposit of calcite, or by a matrix of very fine-grained, subcrystalline stone. Small, irregularly shaped cavities are not infrequent in this brecciated portion. In some places the fractured material once carried an abundance of fossils, but the disturbance which resulted in the shattering of the beds, and the subsequent action of percolating water from which the interstitial materials were derived, have resulted in the destruction to a very large extent of the fossils which the beds originally contained.

Like the *Acervularia davidsoni* coral reef, at a horizon several feet lower, this Stromatoporoid reef forms a well marked and persistent zone in the upper portion of the Cedar Valley stage over the most of the area in which those rocks are exposed in the state. Besides its occurrence at points in Benton and Johnson counties, already mentioned, this bed of Stromatoporoids overlies the lithographic limestone horizon in Mitchell county. It constitutes the "coral marble" of Charles City and Marble Rock, in Floyd county. Its materials compose number 4 of the general section* of the Cedar Valley limestones in Cerro Gordo county, and it outcrops near Cedar Falls and at other points along the Cedar river in the county of Black Hawk.

The members 3 to 5 inclusive, of the Garrison section, are made up of light colored, very hard and fine-grained limestone which contains no fossils. It seems probable that they are the equivalent of the layers of lithographic limestone which occur a short distance below the Stromatopora horizon, further north, in the county of Mitchell.

General Cedar Valley section.—From the sections described above, a general section of the limestones of the Cedar Valley stage in Benton county might be constructed as follows:

*Iowa Geol. Surv., Vol. VII, p. 160.

		FEET.
9.	Bed of light colored limestone, very hard and fine-grained, made up of layers from three to six feet in thickness, brecciated in the upper part and containing numerous Stromatoporoids together with *Gypidula laeviuscula*, *Dielasma iowensis* and casts of *Straparollus cyclostomus*	12½
8.	Bed composed of dense, light gray, fine-grained limestone which is very resistant to the agents of weathering, and contains no fossils, in layers one-half foot to four feet in thickness..	14½
7.	Regularly bedded, fine-grained, non-fossiliferous layers which in some places are impure, magnesian limestone, yellowish-brown in color, and in other places are a gray colored carbonate of lime. The layers vary from a few inches to one or two feet in thickness. Concretions of chert are frequent in the lower portion of this bed..........................	18
6.	Narrow zone of hard, fine-grained limestone, which is usually light gray in color, and contains in abundance disjoined shells of an undescribed species of Spirifer, *Cyrtina hamiltonensis*, a small form of *Atrypa reticularis* and numerous individuals of Camarotœchia cf. *C. prolifica*..........	½–1
5.	Bed of impure, magnesian limestone, yellowish-brown in color and fine-grained in texture, without fossils, made up of rather regular layers which vary from two to twenty inches in thickness, and which contain numerous nodules of chert.............................	10
4.	Bed of variable limestone, the color of which is not constant, and the texture and lithology of which vary at points not widely separated. The following fossils occur in this bed: Favosites sp., Rhynchonella sp., Spirifer sp. and teeth of *Ptyctodus calceolus*. At a constant position near the top the very large and coarsely-striated form of *Atrypa reticularis* is found............	7½
3.	Coral reef composed largely of coralla of *Acervularia davidsoni*...........................	2

FEET.

2. Bed of gray limestone, composed of quite regular layers and carrying numerous fossils throughout. The characteristic species are *Cladopora iowensis*, *Stropheodonta demissa*, *Orthis iowensis*, *Atrypa reticularis*, *A. aspera* var. *occidentalis*, *Spirifer pennatus* near the base, and *Spirifer parryanus* near the top.................................10-15
1. Bed of hard, gray limestone, which bears numerous fossils, among which *Acervularia profunda*, Favosites sp., *Stropheodonta demissa*, *Orthis iowensis*, *Atrypa reticularis*, *A. aspera* var. *occidentalis* and *Productella subalata* are conspicuous.......................... 2-3

From the above general section it will be seen that there is exposed in Benton county a maximum thickness of more than eighty feet of limestones belonging to the Cedar Valley stage. There is a thickness of fifty feet intervening between the Stromatoporoid bed and the *Acervularia davidsoni* coral reef. In Johnson county these two zones are separated by a thickness of only about ten or twelve feet of sediments. The deep bed of yellow colored, magnesian limestone that is so conspicuous a feature of the rocks of this horizon in Benton county does not seem to be represented in the Cedar Valley deposits further southward. To the north in Cerro Gordo county, however, this group of strata attains a development nearly similar. to that found in the county under discussion.

The layers which underlie the coral reef are much more uniformly fossiliferous than those which occur above that zone. The following fossils represent a few of the forms of life which peopled this particular portion of the Devonian sea during the age when the above sediments were being laid down:

Astræaspongia hamiltonensis? Meek and Worthen.
Cyathophyllum sp.
Heliophyllum halli Ed. & H.
Ptychophyllum versiforme Hall.
Acervularia davidsoni Ed. & H.
Acervularia profunda Hall.
Cystiphyllum americanum Ed. & H.
Favosites alpenensis Winch.
Favosites sp. spherical.
Favosites sp. ramose.

Cladopora iowensis Owen.
Cladopora magna Hall and Whitf.
Aulopora sp.
Stromatopora sp.
Monticulipora sp.
Fenestella sp.
Stropheodonta demissa Conrad.
Pholidostrophia nacrea Hall.
Orthothetes chemungensis Conrad.
Chonetes scitulus Hall.
Productella subalata Hall.
Orthis iowensis Hall.
Pentamerella dubia Hall.
Pentamerella arata Conrad.
Gypidula læviuscula Hall.
Cyrtina hamiltonensis Hall.
Spirifer fimbriatus Morton.
Spirifer sp.
Spirifer parryanus Hall.
Spirifer pennatus Owen.
Spirifer subvaricosus Hall and Whitf.
Athyris vittata Hall.
Atrypa reticularis Linn.
Atrypa aspera var. *occidentalis* Hall.
Atrypa aspera var. *hystrix* Hall.
Camarotœchia prolifica? Hall.
Bellerophon sp.
Straparollus cyclostomus Hall.
Conularia sp.
Paracyclas elliptica Hall.

Lower Carboniferous or Mississippian Series.

KINDERHOOK STAGE.

During the time of deposition of the later Devonian limestones that portion of the floor of the Paleozoic sea that included what is now Benton county was slowly rising. The upward movement progressed in a general direction from the northeast towards the southwest. The deposits of the Cedar Valley stage in Benton county were brought to a close when the sea retreated such a distance to the westward that the greater portion of our area emerged from beneath the waters and became a portion of the growing continent.

A well put down on land owned by Mr. W. B. Benson, near the middle of section 30 of Kane township, encountered a bed of shale immediately below the drift. Another well located a short distance south of the middle of section 36 of Iowa township, on land owned by Mr. C. B. Greenlee, penetrated a similar body of shale to a depth of several feet. Other wells drilled in Iowa county, a short distance south of the border of Benton, pass through a thickness of one hundred feet of shale intervening between the drift and the white limestone of Cedar Valley age. Further west, in Tama and Marshall counties, this shale bed is exposed at the surface. At these points where the waters were deeper, and where they prevailed for a longer period, the shale is succeeded by beds of sandstone, oölite and magnesian limestone. This entire series of sandstone, shale, oölite and magnesian limestones constitute the deposits of the Kinderhook age of the Lower Carboniferous series, as those deposits are developed in central Iowa.

In the early part of the Kinderhook age a slow upward movement of the land caused the waters to withdraw entirely from the region under discussion. During the remainder of the Kinderhook and the whole of the succeeding ages of the Lower Carboniferous epoch our area remained above the sea and suffered the constant wasting of its surface by the remorseless agents of degradation.

The Upper Carboniferous epoch was ushered in by a downward oscillation of the earth's crust in which all of the central and southern portion of Iowa was involved. With this subsidence there began the deposits of the Des Moines stage consisting of seams of coal and beds of sandstone and shale, which were spread over the surface of the former lands. Such deposits are not known to be exposed in Benton county, but they occur in the adjacent counties lying to the east, south and west, hence there seems little doubt but that they once covered Benton also, perhaps to a depth of many feet.

The source of the sandstone material may have been the degeneration of crystalline rocks which existed as land masses further northward, or more probably it was derived from the disintegration of the old quartzite highland which at that time

stood above the waters in northwestern Iowa and in the eastern portion of South Dakota.

Several years ago a coal prospector by the name of Caldwell put down a shaft in the south bank of the Cedar river at a point known locally as Barr's bluff. This bluff is a prominent escarpment which overlooks the river near the middle of the north side of section 14 of Benton township. According to the statements of Messrs. Carver and La Tourenne, of Shellsburg, some coal was actually taken from this shaft at a depth of thirty feet.

In the Independence shales of Buchanan county there occur occasional seams of black, highly carbonaceous shale and even thin films of real coal.* Wherever the Independence shales are developed they occupy a horizon immediately below the Fayette breccia. It is probable that the shaft thirty feet in depth at the foot of Barr's bluff encountered this deposit of shale, notwithstanding the fact that ten miles further westward, where the contact of the Fayette deposits with those of the Coggan are seen, the Independence shales are not certainly present. Of course there is no possibility of finding seams of workable coal in the strata of Devonian age.

At the time of the writer's visit to Barr's bluff, during the summer of 1903, there was to be seen a depression that indicated the place of the abandoned shaft, but no fragments of shale or coal or sandstone were found either on the dump heap or at the foot of the bluff or along the bed of the stream.

The scarp is over one hundred feet in height and is composed of the normal series of Cedar Valley limestones. The face of the ledge is somewhat talus covered, but in the bank of a small stream that renders tribute to the river a few rods to the west of the abandoned shaft there are well exposed all of the layers which are embraced between the zone of the very robust and coarse-ribbed variety of *Atrypa reticularis* and the horizon of *Acervularia profunda*, at the base of the Cedar Valley series.

While it is possible that isolated outliers of sandstone of the Des Moines stage may be present beneath the drift in Benton county there is small probability that coal will ever be found in such quantity as to be profitably worked. Our county is

*Calvin: Iowa Geol. Surv., Vol. VIII, p. 223.

east of the coal-bearing area of the state at this latitude. During the Des Moines age the water did not cover this region to such a depth or for a sufficient length of time to permit of the accumulation of coal seams such as were formed further to the west and south.

Before the close of the Des Moines age there was an upward oscillation in the level of the land which once more carried our area above the water, and it never again suffered inundation from the encroachments of the sea. From this time to the close of the Paleozoic era, during the whole of the Mesozoic, and until the Pleistocene period of the Cenozoic the region which now embraces Benton county belonged to the domain of the land. Then, as now, the indurated sediments slowly softened beneath the influence of the air and sun and showers, and after a time a mantle of soil covered the once naked ledges. Plants flourished for long ages upon this ancient surface. Strange forms of animals waged here a watchful warfare for existence. As the slow moving centuries passed away steep hills and deep ravines appeared where once the level coast plain stretched unbroken to the far horizon's rim. As time wore on, the valleys widened, and growing tributaries extended the basins of their major streams on either side. Slowly the contours of the hills became subdued, the slopes gradually faded out and the surface of our land once more approached a plain, the peneplain. With an upward crustal movement the agents of erosion began their task afresh. Again, and yet again, the processes of denudation gradually weakened, only to be quickened and revived as often as a recurring elevation of the land started anew the cycle of erosion.

Of this long interval there remain on our land but meager records. There is left scant history of the successive oscillations, or of the great depth of material that was stripped from the surface. It is certain, however, that some time after an upward movement, while yet the channels of the streams were deep below the level of the uplands, the Glacial epoch of the Pleistocene period was ushered in.

Pleistocene System.

In the Pleistocene system there are two series, the Glacial and the Recent. The latter series includes but a single age, the one in which we live. It embraces all of the time since the permanent withdrawal of the continental glaciers from the north temperate latitudes down to the present. Of the Glacial series there are records in Benton county of the invasions of three successive ice sheets, the pre-Kansan, the Kansan and the Iowan. These long periods of cold were separated by very long intervals of mild climatic conditions, during which streams carved and furrowed the surface, and forms of life much like those of the present peopled the lands.

PRE-KANSAN STAGE.

Pre-Kansan drift—There are no known exposures in Benton county where the drift of pre-Kansan age can be seen at the surface. Its presence is revealed only where the well driller has encountered this deposit beneath a thick mantle of Kansan till. In the northeast quarter of section 29 of Iowa township, a well put down a few years ago on land owned by Mr. Tracy passed through the following succession of beds:

		FEET.
4.	Fine-grained, yellow colored material	15
3.	Blue clay containing bowlders and gravel	210
2.	Layer of gravel and sand	2
1.	Bed of blue colored, bowlder-bearing clay	18

In this record number 4 is the loess or loess-alluvium that forms the surface material near the margin of the flood plain along this portion of the Iowa river. Number 3 is a deep bed of till that immediately underlies the loess over the adjacent portions of the county. It represents the Kansan drift, as the Iowan ice did not move over this particular area. Number 2 is a layer of sand and gravel of Aftonian age. It was probably laid down along the channel of the major stream of this region during the earliest interglacial period. This member is the water-bearing stratum which is the source of the supply of water for the artesian wells around Belle Plaine. At some points this porous layer is much thicker than is

indicated in the section given. Many of the wells that pass through numbers 3 and 4 stop in this water-bearing bed after penetrating it to a depth of twenty-five to fifty feet.

Number 1 of the section represents a bed of pre-Kansan drift underlying the layer of Aftonian gravels. The work of this particular drilling was discontinued when the pre-Kansan deposit was penetrated to a depth of eighteen feet. It is not known what the entire thickness of the pre-Kansan till may be at this place. Since a flow of water is usually found in the second member of the section, few of the wells pass into this older bed of bowlder clay that underlies it.

The pre-Kansan till is not universally distributed beneath the Kansan drift of Benton county. Numerous wells over the region pass directly into the indurated rocks from the Kansan materials without encountering either the Aftonian gravels or the pre-Kansan till. In all of the natural rock exposures the Kansan drift immediately overlies the ledges of Devonian limestone.

Mr. G. M. Tharp, a veteran well driller of the county, is authority for the statement that in some of the wells of Eden, Taylor and Leroy townships a sheet of sand and gravel containing pebbles of foreign origin was encountered beneath a deep bed of bowlder-bearing clay, and overlying the indurated rocks. This gravel bed is doubtless a deposit of Aftonian age, and the presence in it of foreign pebbles bears witness to the proximity, at one time, of an earlier bed of drift from which they were derived. It seems probable that the mantle of pre-Kansan drift was spread quite thinly over the area, and that during the long Aftonian interglacial interval the greater portion of these materials was removed by erosion prior to the deposit of the much thicker bed of Kansan till. Isolated patches of the pre-Kansan drift were preserved only where they were in some way protected from the general denudation that wasted the surface.

From a record of the numerous wells that have been put down in the southwestern portion of Benton county, the southeastern portion of Tama, and the northwestern part of Iowa, Mr. Mosnat* has shown that the Aftonian gravels, and the

*Mosnat: Iowa Geol. Surv., Vol. IX, pp. 521-56?.

bed of pre-Kansan drift that here underlies it, occupy a deep preglacial valley which has an average width of nearly six miles. This ancient channel, which extends in a direction from the northwest towards the southeast, has been traced from a few miles above Vining, in Tama county, across the southwest corner of Benton, and as far south as the town of Ladora, in the county of Iowa.

An interesting fragment of geological history is recorded in this buried valley, and has been made accessible to us through the numerous well borings that have been put down over the region. The channel was excavated in the shales of Kinderhook age. For so long a time did the preglacial stream follow this course that its waters chiseled a channel to the depth of more than two hundred feet and expanded its flood plain to a width of five or six miles.

When the pre-Kansan ice sheet spread over the state its mantle of materials this great valley was not completely filled. Upon the withdrawal of the ice it was once more appropriated by a river which was probably the master stream of the region. About this time, too, the level of the land became depressed to such an extent as to prevent the complete removal of the pre-Kansan drift from the bottom of the preglacial gorge. Along the course of this Aftonian river were deposited the beds of sand and gravel which constitute the water reservoir for the artesian wells of this portion of the state. When the Kansan glacier moved down from the north bearing its immense load of drift,this broad valley was completely buried and every trace of its existence was blotted out. Its presence was never suspected until the exigencies of recent years caused the well driller to probe into its secrets in search of water

KANSAN STAGE.

Kansan drift.—Of all the ice sheets that invaded Iowa the Kansan was pre-eminently the carrier of glacial debris. Over the greater portion of Benton county the Kansan drift has a thickness of from seventy-five to three hundred feet. Mr. G. M. Tharp, of Vinton, who has probably drilled more wells over

this region than any other man, has furnished the following data with regard to the depth of the Kansan till in different portions of the area:

LOCATION.	SECTION	TOWNSHIP.	DEPTH.
Near west side	18	Cedar	175 feet.
Near south side	6	Eden	180 "
Northwest ¼	5	Eden	126 "
Southeast ¼	19	Eden	200 "
Northwest ¼	36	Taylor	175 "
	26	Jackson	215 "
Northwest ¼	31	Big Grove	250 "
Northwest ¼	11	Kane	300 "
Southwest ¼	11	Eldorado	228 "
Northeast ¼	2	Leroy	214 "
Southwest ¼	14	Leroy	175 "
Southeast ¼	19	Iowa	172 "

The Kansan drift was spread over the surface an exceedingly long time ago; so long, indeed, that the erosion of the streams has changed entirely the original features of the topography, and the dynamical agencies have changed very profoundly the chemical and physical constituents of its surface materials. In the deeper deposits the till contains an abundance of lime, and is blue or bluish-gray in color. The clay bears a large number of pebbles of trap and quartz, together with abundant small bowlders of granite and greenstone, and occasional masses of quartz and limestone. The surface of some of these foreign rock fragments is beautifully glaciated on one or more sides. At the top where the material has been long exposed to the action of the atmosphere, and to the influence of meteoric waters and decaying organic matter, the calcareous constituent has been leached downward to a varying depth of three to six feet. Where the surface is broken and the slopes are steep an excess of organic matter is not permitted to accumulate in the soil. Over these areas the iron content of this surface drift, which existed originally in the form of ferrous carbonate, has been oxidized to the ferric oxide condition. In this process the color has also undergone a change so that where sections are exposed in ravines or along the roadsides the top of the drift is a deep red or reddish-brown color due to the anhydrous haematite form of the iron which it contains. This ferretto zone

grades downward to a yellow, which color is imparted to the clay by the presence of the hydrated sesquioxide of iron known as limonite, and this, in turn, passes with a gradual transition into the bluish-gray of the unchanged deeper drift material.

Exposures of the thoroughly oxidized, ferretto zone at the surface of the Kansan drift are numerous over the Kansan area in Leroy and Iowa townships, and they are frequently encountered over the rougher portions of the region later covered by the Iowan ice sheet. Wherever the Kansan drift appears in the county its surface is profoundly eroded, and it is usually overlain by a more recent deposit of loess.

Buchanan gravels.—Beds of moderately fine gravel occur at several points in Benton county, overlying the Kansan drift. This terrane is usually concealed beneath a deposit of fine-grained soil. In section 14 of Benton township a gravel deposit three and one-half feet in depth outcrops in the bank of a stream for a distance of several rods. Another bed of this water-laid material is exposed near the middle of section 19 of Canton township, in the south bank of Wild Cat creek. At the latter place the deposit has a maximum thickness of twelve feet and can be seen continuously for more than a dozen rods. A few miles further east, on Bear creek, a bed of gravel appears a short distance west of Mr. Shannon's brick and tile manufacturing plant, at Shellsburg. This latter is probably the continuation of the deposit that is encountered along Wild Cat creek in section 19. Such beds are also exposed in section 33 of Taylor township, and section 35 of Eldorado.

An area of several square miles in the southern portion of Florence township is covered with this coarse material. Near the southwest corner of section 32 a pit three and one-half feet in depth has been opened on the north side of the wagon road. The presence of a gravel train is revealed in the banks of the most of the streams in this portion of the township. West of the station of Walford this deposit has been utilized in the improvement of the public roads. In Saint Clair township, also, a bed of gravel four feet in thickness has been worked near the southwest corner of section 10.

The gravels that appear in all of the known exposures of the county belong to what Professor Calvin has designated as the valley phase of this formation. They consist of coarse sand and small water-worn pebbles, the latter seldom exceeding one and one-half inches in long diameter. Bowlders do not occur in these deposits. There is only a small amount of iron present, and a rusty color is not generally imparted to the beds. The materials of these gravel trains were derived from glacier-borne debris, and they came to rest along the courses of swollen streams whose waters were liberated by the rapid melting of the Kansan ice.

Professor Calvin* has shown that this lowland phase of the Buchanan gravels was deposited after the glacier had withdrawn from the valleys, and when the ice margin had retreated some distance to the northward: that they were laid down as broad glacio-fluvial aprons after the streams had emerged from the ice bordered canyons and had spread widely over the lower lands. For this reason their currents had lost much of their original violence, and the waters were now carrying and depositing only the finer portions of the debris with which they were loaded when they started with impetuous haste from their source on the shrinking glacier.

IOWAN STAGE.

Iowan drift—The portion of Benton county that was overflowed by the Iowan ice has been outlined under the discussion of topography. This ice sheet left but a scant covering of the finer detritus over the region that it invaded. The large bowlders which it carried are widely distributed, but the proper drift of this age can be seen at but few points over the area. Near the middle of the west side of section 27 of Taylor township the following succession of deposits is exposed in the east bank of Mud creek.

*Calvin: Iowa Geol. Surv., Vol. XIII, p. 68.

		FEET.
3.	Fine-grained, yellow colored clay, containing no gravel	3½
2.	Bed of yellow drift, containing pebbles and small granite bowlders	10
1.	Drift deposit which is blue at the bottom, changing to a yellow color higher up, and at the very top it is a deep red. This bed carries numerous pebbles and small bowlders of dark colored trap	8

Number 1 of the above section represents Kansan drift, the upper part of which presents the typical ferretto character. The contained greenstone pebbles and bowlders are characteristic of this ancient till. Number 2 is a deposit of Iowan drift. It is of a uniformly yellow color throughout. Its superficial portion is unleached of its calcareous matter, and its iron content is not more oxidized in one portion than another. The bed is here much thicker than is usual for this till. The preglacial channel of Mud creek at this point was not completely filled with the Kansan materials, and an exceptionally deep deposit of the later drift was lodged in the depression. Number 3 is a bed of loess. This material does not usually overlie drift of Iowan age, except over the rougher portions of the Iowan plain. The banks which border Mud creek are crowned with loess to a depth of two to four feet, and at this place the loess appears to have slid down from higher up on the hill.

Over the general surface of the Iowan plain typical drift of Iowan age is seldom encountered. It is concealed beneath a true soil of pebbleless material which is black from its contained carbonaceous matter. Even on the gentle slopes fine-grained, yellow colored clay, without pebbles, covers the superficial drift. Where the slopes are steeper the till that is exposed by erosion is usually the oxidized phase of the Kansan. Along the wagon road, between sections 17 and 20 of Saint Clair township, a yellow, pebble-bearing clay resembling Iowan drift was thrown out where recent holes were dug for telephone poles. Large bowlders of granite, gray or pink in color, are spread more or less frequently over the Iowan surface. In sections 14 and 15 of Benton township they are so numerous over some of the fields as to prove serious obstacles to tillage. Mr

Harger has used these rock masses in the foundation of his house and barn, and has built a thick wall of bowlders as a back to his large stock shed. A large proportion of these are of pink or gray granite. There are a few microcrystalline, dark colored greenstones, and less frequently a bowlder of quartzite.

Notwithstanding the fact that the Iowan drift appears at the surface in but few places in the county, it can be shown that the ice of this age covered almost the entire area. The limits of its distribution can be determined by the bordering moraine;

FIG. 18. Iowan bowlders in a field west of the wagon road in section 15 of Benton township. The view illustrates the Iowan topography over the more broken portions of the Iowan drift area.

by the level or subdued topography; by the choked condition of the stream channels; by the presence of frequent, large bowlders of granite; by the general absence of deep beds of loess, and, especially, by the cumulative evidence of a number of the above features which are usually encountered over the same area.

Iowan loess.—The distribution of the loess in Benton county is consistent with the deposits of this material in the neighbor-

ing counties of Tama and Johnson. The thicker beds overlie Kansan drift and are found adjacent to the border of the Iowan plain. Loess forms the surface materials over all of the Kansan area, and mantles the summits and the slopes over the more hilly portions of the Iowan. The material is easily friable, uniformly fine-grained, and is yellow in color. It contains an appreciable amount of lime carbonate, and possesses such tenacity that the banks of streams, where composed of this substance, stand for a long time with almost vertical walls. The deeper deposits show no well marked evidences of stratification, such as characterize sediments laid down by water. These beds often contain in abundance shells of air-breathing gastropods, which are indiscriminately distributed throughout their entire depth. The loess was laid down upon the very ancient Kansan surface which had suffered practically as much erosion, leaching and oxidation before the mantle of loess was spread over it as it shows today. This deposit does not tend to level up the inequalities of the surface, but forms a veneer alike over the summits, slopes and lowlands. Often the beds are even thicker on the crests of the ridges and the higher portions of the hills.

When the Iowan glacier was at its maximum the ice was thinner over the higher areas. As a consequence these prominences were bared earliest as the ice melted. As soon as the hills were uncovered, and while the ice still lingered over the surrounding lowlands, the higher points would receive a thin deposit of this fine-grained material in a manner similar to that of the hills bordering the Iowan plain. In this way it seems possible to explain the presence of loess over the more broken portions of the Iowan drift surface. Professor Calvin* has shown that the loess materials of eastern Iowa were largely derived from the finer constituents of the Iowan drift. They are probably in the nature of glacio-aeolian deposits with possibly, contiguous to the Iowan margin, some overwash of the finer materials as the ice melted. They were probably laid down during the time of the greatest advance, and immediately succeeding the withdrawal, of the Iowan glacier. It is worthy of note that the loess of Benton county is not stratified. It con-

*Calvin: Iowa Geol. Surv., Vol. VII, p. 89.

forms to prior inequalities, and does not tend to level up the surface. The contained fossils are those of air-breathing, terrestrial forms, and the shells, though exceedingly fragile, are unbroken.

Post-glacial or Recent Deposits.

ALLUVIUM.

Deposits of superficial materials later than those of the Glacial series occur at various points in Benton county. Over the broad flood plains of the Iowa river and the larger of its tributaries there is a mantle of alluvium that was laid down during the Recent age. Along a portion of the channel of the Cedar river and the lower courses of its principal branches rich, fluvial sediments have also been spread over the level bottoms. These deposits are usually dark in color, and rich in carbon-bearing and nitrogenous compounds which have been contributed by the imperfect decay of successive generations of the rank, semi-aquatic vegetation that flourished over the fertile lowlands. During times of overflow the stems and leaves of such plants were effective agents in entrapping the suspended sediments. Each inundation added a thin increment to the surface of the deposit, and each season's growth yielded an increased store of plant food for the crops of succeeding years. In this manner has been developed the extreme fertility of the alluvial deposits.

CUMULOSE DEPOSITS.

When the Iowan ice sheet retreated to the northward it left a somewhat uneven surface, the depressions over which became occupied by lakes. Many of these glacial lake basins are represented at present by swampy or marshy tracts. The transformation from lake to swamp and, in some cases, from swamp to fruitful field has been accomplished since the retreat of the glaciers. As the wind swept the land surface year after year a portion of the fine detritus that it gathered came to rest on the water of the lakes, and slowly sank to the bottom. With

every freshet each streamlet that trickled down from the encircling swells carried a tiny load of silt. These lakes were also shallowed as water lilies and other aquatic forms established themselves in the pools, and pond-loving plants encroached upon the shores. These all, at death, gave up their substance to swell the accumulations which, through the centuries, have filled up, and banished the water from the most of the lake basins. Such deposits of humus or swampy soils, containing a very high percentage of organic matter, are frequently encountered over the surface of the Iowan drift plain.

AEOLIAN DEPOSITS.

The more typical examples of aeolian deposits in Benton county are the beds of sand and mantle of loess that occur over the rougher portions of the area. It is probable that the most of these materials were laid down during the time of maximum extension of the Iowan ice sheet. It seems altogether probable, too, that a large amount of these materials have been shifted and redistributed, and the entire aggregate appreciably augmented during the Recent age. A considerable amount of the inorganic ingredients of the soils has been carried and deposited by the wind since the close of the Glacial epoch, and even now the process of soil formation is going on.

Soils.

Soils are composed of comminuted and more or less decomposed fragments of rock material with which is mingled organic matter from plant and animal decay. The fertility or productive power of soil is dependent upon both its chemical composition and its physical condition. The chemical composition of any soil, aside from its humus, is largely determined by the character of the rocks from which it was derived, and by the amount of washing, leaching and oxidation to which it has since been subjected. The desirable physical condition of any soil can be largely controlled by the continued practice of appropriate tillage. Where nature's methods are not interfered with, each season's growth of vegetation returns to the

soil, with interest, the food compounds that were extracted in its production. When man steps in and harvests the crop he robs the land of nature's annuity and the soil deteriorates, unless intelligent modes of tillage are employed.

The inorganic ingredients of the soils of Benton county have all been transported either by wind, water or ice. None of the soils are residual. There are present in the area five more or less distinct soil types: loess, Iowan drift, swamp, sand, and alluvium. In many places these types grade one into another and not infrequently the soil at a particular point is a mixture of the materials which characterize two or more of the above divisions. These different types of soil are due largely to the difference in the materials which form the subsoil or base upon which each has been developed.

1. *Loess soil.*—Loess soil occurs over all of the Kansan drift portion of the county. This area is so hilly that little humus has been permitted to accumulate in the superficial material of the slopes. As a consequence the loess soil is a yellow clay. The color here, like that of most yellow soils, is due to the presence of the hydrous sesquioxide of iron. The loess is fine-grained in texture yet the particles are sufficiently large to permit the ready passage of water, and to render the soil light, and tillage easy. At the same time the soil particles are so small that moisture is readily brought upward from below by capillary action. This soil is rich in lime which mineral Hilgard* considers more effective than any other in controlling soil fertility and in making it loose and porous, thus permitting good ventilation and favoring the thorough and uniform penetration of the rootlets of plants.

Over level areas the loess soil is durable and very productive. Where the surface is broken the constant rain-wash prevents the development of organic matter in the soil, and rapidly leaches away necessary constituents of plant food. Where such areas are cultivated the disastrous washing of stream erosion, in addition to the strong leaching, speedily wastes what fertility the soil once possessed. See figure 14. Such

*Hilgard: Bulletin No. 3, U. S. Weather Bureau. 1892.

devastated fields yield scant returns for the labor expended in the effort to produce a crop. When the original soil mantle has never been disturbed the slopes support an excellent growth of native blue grass which, when pastured, improves with the passing years.

2. *Drift soil.*—The typical Iowan drift soils are found over the most of the prairie portions of the Iowan plain. They are a deep, rich loam, containing grains of rock-meal sufficiently large to make the soil light and warm, and to prevent puddling during seasons of excessive rainfall. The color is almost black on account of the wealth of carbonaceous matter that it con-

FIG. 14. Some results of disastrous rain-wash of the land. View looking down the Cedar river in section 10 of Benton township; showing the sand bars and willow-grown mud-flats in, and bordering, the channel of the river.

tains. Iowan drift is typically yellow in color. It is possible that the abundance of vegetable matter in process of slow decay in these black soils has resulted in changing the form of a part of their iron content from the original condition of hydrous ferric oxide to the form of ferrous carbonate. When

in the form of carbonate the wealth of organic matter in the soil would prevent the oxidation of its iron constituent. All of the desirable qualities that are imparted to soils by the presence of lime are possessed by those of the Iowan drift. The surface of these favored areas is level, or gently undulating, so that the slopes are not rapidly leached, nor are they impoverished by the washing effects of rain storms.

The finer material of the drift soils consist of "rock-flour" and "rock-meal," which have been derived from the grinding up of the rocks carried in the ground moraine, and of those at the surface of the ledges over which the glacier moved. By this mode of origin even the finest of the mineral constituents have not suffered complete oxidation and decay, as have those of sedentary soils which have resulted from the degeneration of rocks in situ. Chemical changes are at present taking place in the particles of this recent soil through the agency of air and water and organic matter. In this process soluble compounds suitable for plant food are constantly being liberated. This constant increase in the mineral elements available for plant food, the wealth of organic matter which they possess, and their texture which favors the conservation of moisture, all contribute to render the soils of the Iowan drift exceedingly fertile, and almost inexhaustible.

3. *Swamp soil.*—Isolated areas of swamp soil are quite frequent over the Iowan plain. They represent the partially filled basins of glacial lakes. Many of these marshes are still so poorly drained that water stands over them during long continued rains. The characteristic component of these soils is the black, mucky material with which is mixed a small percentage of mineral matter. These soils are sour and cold. When cultivated the application of lime * would be beneficial in overcoming the acidity and making the soil more porous. Such soils are wanting in ventilation. Almost their only means of aeration is where crayfish have excavated their wells and underground channels. It is estimated † that 40 to 50 per cent of the full water capacity of soils must be drained away before good yields of cultivated plants can be secured. When these

* Roberts: The Fertility of the Land, pp. 307-314.

† King: The Soil, p. 161.

areas have been thoroughly underdrained, and the soil has been stirred deeply for a sufficient length of time for the air to accomplish the more perfect decay of their organic matter, these soils become loose and light, and rank second to none in productiveness.

4. *Sandy soil.*—A small amount of sand mingled with a large percentage of materials of finer texture forms light, loamy soils of the highest quality. Where the percentage of the ingredients is reversed there results a sandy soil which, unless supplied with an abundance of water, is comparatively unfruitful. Areas of sandy soil are common in the western portion of Harrison township, the southern part of Polk, and over portions of Benton and Taylor. Such soils are light and open. They permit rapid leaching. Even over the more level areas they contain little humus. They are usually poor in organic matter and deficient in soluble mineral compounds essential for the food of plants. They are so porous that their power to retain moisture is small. Their interstitial spaces are so large that water is not readily brought upward by capillary action when evaporation from the surface is rapid. These sandy soils are, when cultivated, the most barren and infertile of any of the soils of the county. It is fortunate that their aggregate area is small.

5. *Alluvial soil.*—The alluvial soils of Benton county are usually a rich loam whose mineral constituents have been derived from the uplands and spread out over the level areas of flood plain. Such soils usually contain a wealth of organic matter which imparts to them a dark, almost black color. They are warm and mellow, never becoming baked or water-clogged after excessive rains. They are usually underdrained by porous beds of water-laid sand. There is generally present a sufficient amount of fine-grained clay to impart to these soils a good capacity to retain water and to furnish efficient capillary action during periods of drought. The successive deposits of the streams have supplied these alluvial soils with all of the fresh mineral compounds with which the drift of the uplands is so richly endowed. All of the necessary elements of plant food are abundant and in such soluble form as can be readily utilized by the growing crops. Where these areas are not subject to

overflow the alluvial soils respond most generously to tillage; they are the most uniformly warm and mellow, the most fertile and highly productive of any of the soils in the county.

Unconformities.

The contact between the Coggan beds and the Fayette breccia is exposed for only a short distance in the county, but where it can be seen the transition is abrupt. From what is known of the relation between the rocks of these two horizons further east, there seems to be no doubt that the deposits of the Fayette sub-stage rest unconformably upon those of the Coggan. Between the rocks of the Wapsipinicon and the Cedar Valley stages there is no distinct line of separation, and no indication of unconformity.

The earliest sheet of drift was spread over the preglacial surface of indurated rocks after an enormous interval of erosion. In no case is there conformity between the deposits of the successive ice invasions, and in every instance there is conspicuous unconformity between the loess and the drift over which it lies.

Deformations.

In the strata of Benton county there are encountered a few slight flexures but no very conspicuous deformations. The most marked example occurs where the Coggan beds are exposed along the bank of the Cedar river with a depth of fifty-five feet of the Fayette breccia overlying them. About two miles south of this place the rocks of the *Spirifer pennatus* beds outcrop on the opposite side of the valley only a few feet above the flood plain of the river. Between these two points there is indicated for the beds of *Spirifer pennatus* a difference in altitude of more than fifty feet. Near the Benton-Linn county line a narrow lobe of limestone, embracing the *Spirifer pennatus* beds, extends into the flood plain of the Cedar river, the

strata here form an arch on either side of which the layers slope downwards at an angle of about 45 degrees. See figure 15.

At the Cedar River exposure the layers of Cedar Valley limestone have a conspicuous dip towards the south. A few rods north of this bluff, just across a ravine, is Long's quarry where the dip is in the opposite direction. The intervening stream occupies the axis of a gentle anticline, on either side of which the strata slope away at the rate of about twelve inches in a distance of forty feet.

FIG. 15 Hog-back jutting into the valley of the Cedar river near the Benton-Linn county border. The strata belong to the *Spirifer pennatus* horizon, and the inclination of the layers is about 45 degrees.

At John Tripp's quarry the layers are inclined towards the south even more strongly than at either of the above mentioned exposures. At McKinley's quarry also the rocks do not lie in a perfectly horizontal position. The slight inclination of the layers at some of the above points may be due to inequalities of deposition, owing to the unevenness of the sea floor upon which the sediments were spread.

ECONOMIC PRODUCTS.

Building Stones.

Coggan beds.—The exposures of Coggan limestone, in section 36 of Cedar township and section 6 of Taylor, furnish the best quality of building stone found in the county. The rock is yellow, very hard, fine-grained and strongly magnesian. The ledge outcrops almost continuously at the base of a bluff for a distance of nearly one mile. At the west end of this exposure Mr. Wallace operates a quarry in the Coggan layers. One-half mile further east Mr. Kearns has worked in the same ledge, and still further eastward, along the Cedar river, Aungst Brothers have taken out a large quantity of stone. The one serious disadvantage that attends the getting out of this stone is the fact that it is overlain by several feet of thoroughly brecciated deposits of the Fayette sub-stage. The great expense of stripping, and the lack of shipping facilities limit the output of these quarries to the local demand.

Fayette breccia.—At several points near Vinton quarries have been operated in the layers near the upper part of the Fayette sub-stage. The old Bliss quarry, which formerly furnished the mineral used by the Iowa Paint Company in the manufacture of paint, was worked in the horizon of the *Spirifer pennatus* beds. The lower layers worked at the Quinn quarry lie in the same zone. The Rosenberger quarry stone is also furnished by these fractured beds At the Pettit quarry, stone is taken from both the Gyroceras horizon and that of *Spirifer pennatus.* As a general thing the rocks in the above zones are badly shattered. The stone that they furnish is in rough, irregular blocks, suitable only for rubble and for rough masonry. The deposits of the Fayette breccia furnish a suitable grade of material for making concrete and macadam, and for general road building.

Cedar Valley limestones.—A large percentage of the stone quarried in the county comes from the layers of the Cedar Valley stage. In the vicinity of Shellsburg there are worked beds which lie between the *Acervularia davidsoni* and the *Acervularia profunda* horizons. These layers furnish a grade of

stone that can be used in cellar walls and foundations for common buildings. The local demand of the region, in and adjacent to the town, is supplied from these beds.

In the northern portion of the county the best quarries are operated in the magnesian layers which overlie the zone of the very large, coarsely-striated type of *Atrypa reticularis.* Long's quarry and Keiser's quarry, on the Cedar river, furnish the most of the stone from this horizon. The quality of the output at these quarries is excellent. Blocks with parallel faces are taken out in almost any dimensions desired. The stone is easily shaped and is very serviceable for all kinds of common range work. Where the undisturbed ledges have been exposed to the air for a long period they show a good degree of resistance to weathering. This fact would furnish the very best evidence of the powers of endurance of the stone when laid in a wall. The most of the stone used in the piers of the Mount Auburn-Brandon bridge across the Cedar river came from these layers.

Near the town of Garrison the rocks that have been worked embrace the Stromatopora horizon and about twenty feet of the layers which normally underlie those beds. The hard, fine-grained layers of white limestone vary from one to three feet in thickness. They are not so easily worked as are the magnesian layers lower down, but for a nearly pure limerock, they furnish material of a durable quality.

Rock exposures are so widely distributed over the north half of the county that stone for general purposes is readily accessible from every point. At none of the quarries is the equipment expensive. None of them supplies a demand larger than that of the local territory. At no single place is there a very large quantity of stone produced, but the total output from all of the quarries would aggregate an important sum.

Lime.

Lime is at present manufactured at but one point in the county. The stone used for this purpose comes from the Coggan beds in Taylor township. This material is sufficiently dolomitic to make a very excellent quality of lime. For several

years Aungst Brothers have annually burned a kiln, with a capacity of seven or eight thousand bushels, to supply the local market. The more strongly magnesian layers at Long's or Keiser's quarry would furnish suitable stone for lime burning. Some years ago Mr. Long was accustomed to burn an occasional kiln, but of late he has abandoned lime production.

At various places in the state, stone which corresponds with the white limestone layers of the quarry near Garrison has been used in the manufacture of lime. The superior quality of the product made from dolomite has caused the burning of the more pure calcium carbonate to be discontinued. Lime is at present manufactured on a large scale at exceptionally favorable points in eastern Iowa. The excellent transportation facilities, together with the good keeping qualities of dolomite lime, make it possible for the large concerns to supply the markets of the state more cheaply than lime can be burned locally in small kilns.

Road Materials.

Materials suitable for permanent road building are abundant, and fortunately located, over the county. The numerous rock exposures in the townships of Cedar, Harrison, Polk, Benton, Taylor, Jackson and Canton would furnish an unlimited supply of stone which, when crushed, would make an excellent macadam. These outcrops are so readily accessible from all portions of the area that no long hauls would be required to cover all of the main lines of travel with this material. Along the north bank of Pratt creek, in Cedar township, the thoroughly brecciated phase of the Fayette deposits appears at the surface for a distance of half a mile. The fragments here are incoherent, and are so small that, without crushing, they are ready to be taken out and applied to the roads. While no exposures of indurated rocks occur in the townships of Bruce, Monroe, Homer, Big Grove and Eden, yet such deposits are encountered but a short distance beyond their borders.

In the southern portion of the county, where the rocks are buried deeply with the drift, there are occasional beds of gravel

which furnish a cheap and very satisfactory material for road making purposes. Gravel trains outcrop in Saint Clair, Florence, Eldorado, Canton, Taylor and Iowa townships. These deposits lie near the surface and are easily worked. They have been used with excellent results on the wagon road between sections 25 and 36, in Florence township, and also on the road crossing the middle of section 24 of the township of Iowa.

Sand.

Abundance of sand well adapted for use in mortar, cement or plaster occurs at a number of places in the county. Large quantities are annually taken from the flood plain of the Cedar river, and the larger of its tributary streams. At Vinton the supply for building purposes is drawn almost exclusively from the river's bed within its limits. Hills of sand of requisite purity and quality for general purposes occur in Polk, Taylor, Harrison, Iowa and Leroy townships. The sand used at Shellsburg is taken from the channel of Bear creek close at hand. The bed of the Iowa river and of Prairie creek contain a large amount of common, clean sand which supplies the demand of a large area in the southern portion of the county.

Clays.

Clays suitable for the manufacture of common brick and drain tile are widely distributed over the area under discussion. The only deposits utilized are the loess and alluvium. For the production of the cheaper grades of common clay goods these beds furnish a supply of raw material that is excellent in quality, inexhaustible in quantity, and inexpensively worked. Clay goods have been manufactured at the following points:

Vinton.—For some years Mr. V. W. Aikley has produced brick and tile on a small scale at Vinton. The equipment at this place is not expensive. Only a single temporary kiln is burned at one time. The value of the annual output does not exceed $2,000. Mr. Aikley has given more attention to the

making of brick than of tile. He finds a ready market for his products in his home town. The clay used is a mixture of loess and alluvium which is taken from the valley of Mud creek.

Shellsburg.—A large brick and tile manufacturing plant is operated at Shellsburg by Mr. Samuel Shannon. The cheaper grades of construction brick and all of the common sizes of farm drain tile are produced at this place. This is one of the largest plants in the county. The machinery is of the most approved type, and the wares produced are of superior quality. The clay pit is worked in the bed of Bear creek and the material is a modified drift and loess-alluvium.

Garrison.—Brick and tile are produced on quite a large scale at the town of Garrison, by Messrs. Deutremont and Gross. A good market is furnished for drain tile by farmers over the surrounding, level areas of the fertile Iowan plain. The demand for the clay goods produced at this place is local, but all of the needs of the area in this line are supplied by the home factory. The clay is taken from the flood plain of Hinkle creek. The plant is equipped with up-to-date machinery and the products are of excellent grade.

Norway.—At the town of Norway a brick and tile factory is owned and operated by Charles Trajorsky. The clay pit is located in the loess at the east end of the Norway paha ridge. The equipment includes an Anderson soft mud, and a Nolan and Meaden stiff mud brick machine. The tile machine is of the same make as the stiff mud brick. There are two round, down draft kilns, with brick capacities of 40,000 and 50,000 respectively. All of the wares are air dried. Tile of the usual sizes, from three to eight inches in diameter, are made. The chief market is in the town and the splendid farming district adjacent, within a radius of ten or a dozen miles. Wood is the fuel used. The plant is arranged more especially for the manufacture of tile than of brick. The total value of the combined annual output of brick and tile is between three and four thousand dollars.

Belle Plaine.—Brick is made to supply a portion of the local demand at Belle Plaine, by Mr. Frank Smith. Only the cheaper

grades of construction brick are manufactured. The kilns are temporary and the machinery inexpensive. The clay used is taken from a bank of loess.

Newhall.—Mr. E. H. Morrow, at Newhall, manufactures both brick and tile. The demand is largely for tile and comes from the farmers over the level Iowan drift area whose farms are improved by the underdrainage.

The value of the total output of brick and tile in Benton county would aggregate more than $24,400. No single plant manufactures a much larger quantity than the demands of the immediate locality warrant. Freight rates are so high that little of the clay products are shipped to other points by rail, and, likewise, but a small amount of the common clay goods used in the county are imported. The several plants are so distributed as to place such wares within easy reach of every point in the county. Since the advance in the price of land of recent years, there has been a large demand for drain tile on the part of farmers over the Iowan area. With proper underdrainage the most level fields are productive, even in seasons of excessive rainfall.

Copper.

Some years ago a nugget of native copper was found by Mr. Conrad Burkhart near the river, in the southern part of Polk township. This fragment was encountered in the drift about six feet below the surface, as parties were digging a well. The mass weighed six pounds and nine ounces, and is almost pure copper. About one year ago a similar mass, weighing twenty-seven pounds, was found near Toledo, in Tama county. The surface of these fragments is covered in places with a thin film of green malachite, or copper carbonate, which has been formed by alteration of the native copper since it left the parent ledge. Such nuggets have been found at several points in Iowa. They always occur in the bowlder clay, never in the native rocks of the state. The original home of these fragments was probably the copper bearing rocks of the Lake Superior region. The masses

were doubtless distributed over the surface of Iowa by the glaciers in the same manner, and at the same time, as the foreign bowlders of granite and crystalline rocks which form such conspicuous features of the drift material. The presence of occasional pieces of copper in the drift offer absolutely no indication of deposits of copper ore in the native rocks of our state.

Water Supplies.

Almost everywhere in the county shallow wells find in the drift a bountiful supply of pure water at a depth ranging from twenty-five to seventy-five feet. The Cedar river and the Iowa furnish an abundant and permanent water supply to the regions through which they flow. The larger tributaries of the major streams have their sources in the boggy springs over the Iowan plain, and their perennial flow supplies stock water of the finest kind to the farms over large areas. The town of Vinton obtains its water from two deep wells which penetrate the Saint Peter and the underlying sandstones. One of these wells has a depth of 1,172 feet, and the other 1,287 feet below the surface.

The southwestern portion of the county is embraced in the Belle Plaine artesian basin. These flowing wells derive their water from the porous gravels that here underlie the Kansan drift, at a varying depth of from ninety to three hundred feet. A number of such wells occur in Iowa township, and a few are found in Kane and Leroy. These artesian wells furnish an ideal supply of water for farm purposes. The water carries such a high percentage of minerals, notably calcium and magnesium sulphate, that it is not suitable for drinking or culinary purposes. It possesses no valuable medicinal properties. It contains such quantities of incrusting and corroding salts that it is unsuitable for use in steam pipes and boilers. Some years ago the Chicago, Milwaukee and Saint Paul railway company put up a round house and other large buildings at the town of Van Horn. On account of the pipe consuming and incrusting minerals in the water at this place the works have been abandoned, and the buildings are now unused.

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THE GEOLOGY

OF

EMMET, PALO ALTO AND POCAHONTAS COUNTIES.

BY

THOMAS H. MACBRIDE.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Geology is withal a most comprehensive, all embracing science. Its problems are wide as the world, far-reaching as time, coëxtensive with the universe entire. The geology of a locality, a single county, or even of two or three counties, might seem, therefore, at first glance impossible. Here is room for suggestion only; no adequate field for the display of any such wide-extended problem; no scope for adequate study much. less for the solution of any of the vast and intricate questions which our most superficial inspection is sure to raise, and which, in fact, immediately confront the student on every side. Especially do such limitations appear when one attempts the study of one or more of the counties of northwestern Iowa. Here the usual factors of geologic study are almost entirely removed from human ken, all alike buried, often hundreds of feet deep, by confused and mingled drift; the very drift itself less accessible owing to the minimum effects of ordinary erosion. Only surface indications and features are at the disposal of the man of science, and these, many times, precisely of the sort requiring wide comparison for full or even helpful explanation. Surely the problem of the geology of a northwestern Iowa county promises but small returns even for the most enthusiastic industry. Nevertheless, such is the wide extent of present investigation about the world, that where the experience of the individual student fails him in his narrow field, the labors of others come to his relief, and thus even the problems of a single county, a single township, may, and do become intelligible as forming at least a part of some wider, vaster whole.

Thus we approach our present study. The three counties named in the title form part and parcel of our great northwestern prairie; apparently all alike, to the extent even of wearisome sameness or monotony, and suggesting very little at

first sight of what might go to elucidate the history of the world; and yet, after all, in itself a part of the outcome of all that history, and in itself, therefore, a fact, whose explanation, here as elsewhere, lies largely in the fact concealed, or even revealed; much as the peculiar names of the counties carry with them, for him who can understand, a curious revelation of the history of our composite people.

Emmet. Palo Alto, Pocahontas, these three counties constitute a strip of prairie, in width exactly twenty-four miles; in length, some sixty-six; since from Emmet the northern tier of townships is missing, along the Minnesota line. On the east lie Kossuth, Humboldt, and a part of Webster county; on the south is Calhoun county; while to the west are Dickinson, Clay and Buena Vista. Nearly all of these surrounding counties have been described in these reports; as to the three immediately in hand, their place in the history of civilization dates back only a few decades, forty or fifty years, at most, and in the books of science they have hitherto had scarcely mention.

PREVIOUS GEOLOGICAL WORK.

Dr. White, in his sketch of northwestern Iowa, includes these counties with a brief description.* He was apparently especially impressed by their altitude, their relationship to the general watershed of the state, and to the drainage system of the Des Moines valley. He admired the abundant lakes and pools that gave a certain variety to the otherwise monotonous prairie landscape, and referred these correctly for their origin to the deposition of the all-embracing drift. The same distinguished author realized to some extent, at least, the depth of this same drift, and, knowing the geologic structure of the eastern half of the state, he announced the improbability of mineral wealth beneath these wide deposits, warning the people of the state that shafts sunk in search of coal were almost sure to result in disappointment. He saw, however, the native species of forest trees, here and there wide-scattered, struggling, and even flourishing, wherever they had covert from the

* Rep. of the Geol. Survey of the State of Iowa, by Charles A. White, M. D., Vol. II, pp. 215-219, 1870.

annual fires, and predicted that a few years would suffice "to convert the whole of this treeless space into a well cultivated region with a sufficient amount of artificially planted woodland from which to supply the wants of the inhabitants."* It would be a satisfaction to this pioneer student, geologist and long honored author, could he today personally realize how completely his predictions in this regard have come to their fulfillment.

Aside from the work of Dr. White the counties we now consider have had no attention from student, geologist or geographer. Of no remotest interest to the miner, their fertile, peaceful acres have fallen under the plough and have been forgotten or remembered only as political bits of Iowa's vast farm.

Nevertheless these counties are not without their own scientific interest, and afford within narrow limits much to occupy the intelligent farmer or student, much to tax the ingenuity of the wisest who seek to offer satisfactory explanation of the diverse local phenomena everywhere displayed. Topographic problems are offered by every township, almost by every square mile, and, as for structure, our limited knowledge finds opportunity for enlargement after each erosive freshet, might gain new pages at the sinking of each new country well or the digging of each county-ditch, almost each cave or cellar. There are hills and plains and valleys, mostly hindrances rather than aids to the farmer's plans and industry, there are rivers and creeks and lakes, but often owing to each other only remotest, most indefinite allegiance; there lie beneath our feet, rocks and gravels, sands and clays, but all in confusion mingled. We have but begun to classify these strata as they lie, to interpret their far-reaching history. Even the boundaries of the more general divisions into which the soil elements of northwestern Iowa naturally fall are often difficult of discovery, and an accurate mapping will require months and years of patient research in the field.

The present account is, therefore, but a sketch, a preliminary study, as have been its predecessors dealing with the neighboring counties. To assemble all these partial pictures, correct

* Rep. Geol. Surv. of Iowa, by Chas. A. White, M. D., Vol. II, p. 215.

them, and at length unite them in some more perfect and general composite view or portrait of this unique and wonderful section of our prairie state remains the much-needed labor of some future day.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of the counties before us, at closer view, is sufficiently varied. Although to the eye of the passing traveler often apparently perfectly level, yet the entire country slopes gently to the south and is likewise higher at the western side, for reasons presently to appear. The variation in level is, however, often surprisingly small. On a later page appear the altitudes of several towns as given by the respective railways in each case. These railway levels may with interest and profit be compared. Ruthven, on the western edge of Palo Alto county, is the highest town in the territory mapped, and Rolfe is the lowest; the difference between them is two hundred and seventy-five feet. This, however, gives an exaggerated view of the matter on account of the unusual altitude of Ruthven, perched high on the morainic hills. If we compare Estherville in the north with Fonda of the extreme south, we have a difference of only fifty-two feet. These points are almost exactly on the same meridian. If, however, we draw a line from northeast to southwest, as from Armstrong to Fonda, the variation falls within five feet; Cylinder, Rodman and West Bend are within two feet of the same level; and so, many such comparisons may be made.

Nevertheless, with all this apparently common altitude, the variation in topography in the three counties is by no means inconsiderable. There are hills and valleys and plains here as elsewhere, but their succession is different; they stand in peculiar relation to each other. The hills are some of them high and precipitous, as in Walnut township of Palo Alto county, or Emmet township of Emmet county; sometimes they are simply low swells or mounds, as about Maple Hill or Em-

metsburg. All these are altogether independent of erosion. No streams run among the high hills about Ruthven or Graettinger; nor more among the mounds, of Armstrong or Curlew. These are hills of construction, i.e. they were piled up and abandoned here by an agency of which they are at once result and evidence, an agency in the ages past efficient over wide areas, determining the shape and features of the land surface of a considerable portion of the northern world—the agency of glacial ice. Erosion affects these hills, no doubt, today, as it has for centuries, but it did not make them. This is evident to anyone who will give the subject the slightest study or examination. There are hills of erosion also here although often, generally, insignificant. These may be noted along all streams; along the Des Moines, although here rarely in this region. The Lizard in its winding branches shows now and then an eroded slope; even the upper channels of Cylinder creek show gently sloping, eroded fields. Beaver creek, near Rolfe, shows perhaps more of erosion topography than appears elsewhere in the three counties. This stream seems to have cut down pretty rapidly to the level of the Des Moines flood plain and so shows steep inclines, not a few in the neighborhood of Rolfe and northward. Beaver View farm is a fine illustration. You may find erosional hills in this, our present territory, but by search. The hills we easily study are morainic hills, constructional, as said, owing their existence to forces acting long ago. Consequent here may be noticed the peculiar distribution of these hills. They occur chiefly on the west side of the Des Moines river. Beginning at Estherville and thence south, the hill-country is nearly all on the right bank of the river. There are swells and mounds here and there, everywhere, but for hills, everybody sends the traveller west. And there he finds them sufficient in numbers to raise the general average level, as we have seen, of all the west side of our territory; sometimes grouped together, like miniature mountain chains, a hundred feet high, as about Ruthven and west of Graettinger. In fact this country is so rough and uninviting as to have been only recently occupied. A big church crowning the hilltop here and there tells of some Swedish or Norwegian

colony, newcomers with old time Norseman courage, daring what others have neglected. Between the hills watercourses are most imperfect, but aided now by ditches give to the agriculturist some advantageous variety, lowland meadow and upland slope.

While, as stated, these peculiar hills are characteristic and best displayed west of the Des Moines, yet they are by no means lacking in other places. They are prominent north of Estherville, about Dolliver, and extending in broken series in a southeasterly direction past Armstrong. There are low ranges of them in the vicinity of Emmetsburg, especially about two or three miles east of the city; they occur northeast of Rodman and about West Bend. A very interesting specimen, because of location, is found directly athwart the highway east of the town of Rolfe, precipitous all around and forty or fifty feet above the surrounding level.

Associated with morainic hills are always lakes of greater or less dimensions, these in the present instance are neither few nor insignificant. There are lakes in each of the three counties; in Emmet county they are especially numerous. Some of these may claim special description.

Iowa lake, which names for us the northeastern township of Emmet county, lies mostly in Minnesota. In Iowa it covers not more than one square mile, but is withal an attractive and permanent body of water, bordered, especially to the north, by native groves of all the commoner species of our native trees. The lake has no Iowa affluents, but in this year (1903) the outlet, tributary to the Des Moines (?), is a rushing torrent.

Turtle lake, or as the people of the county now prefer lake Okamanpadu, is very much larger than Iowa lake but similar to this lies much of it north of the state boundary. Altogether it covers some four square miles. This lake too is bordered by native woods, once much more extensive than now. The Iowa shores are today nearly destitute. Still the lake is picturesque and beautiful, apparently one of the abiding attractions of a beautiful rural landscape. This lake is also one of the sources of the Des Moines river. It seems to have two outlets one to the east, the larger, to the East Des Moines; the

other flows west to Soldier creek which is itself, however, farther on a tributary of the same stream. Immediately south of Okamanpadu is Swan lake, by far the finest body of water in Emmet county. Lake and swamps together, Swan lake affects half a dozen sections and extends more than six miles from east to west. However, the east end is but a wide marsh full of rushes and all aquatic vegetation. Swan lake proper is at all seasons a fine sheet of water surrounded by good banks, some of them high and generally covered with native woods; trees of the finest varieties; beautiful primeval walnuts still standing. The depth this year is reported fifteen to twenty feet. Singularly enough, the locality is comparatively high. From the west end of the lake the view extends for miles in every direction; the wooded, high, western banks of the West Des Moines river stand like a wall of green; the village of Raleigh appears beyond, while on this side Graettinger, Wallingford, Gruver, Dolliver, and even the groves of Estherville are plainly visible. Yet here is no highland, as such, visible to the eye; this is a lake-shore and the flatness of the far-reaching plain alone surprises the beholder. On the west side of Emmet county are several small lakes, as Four-mile lake, Chester lake and Twelve-mile lake. The last named is possibly the largest and most permanent of these, but all are shallow and likely to be drained and made over into cornfields once the county surveyor with his ditch arrives.

Palo Alto county likewise boasts of several lakes. Lost Island lake, lying partly in Clay county, is a beautiful and permanent body of water, to be classed with Spirit lake and Okoboji. While not quite so large as the former, nor so deep as the latter, it is none the less attractive and has about it the same picturesque hills and winding beaches. Lost Island lake has an expanse of some three or four square miles and is said to be twenty feet in depth. The southern shore has been laid out as a park and affords place for summer cottages. North of Lost Island lake, in Palo Alto county, is a wide marsh as large almost as the lake itself, but distinct, once known as Pelican lake. These lakes are both situated in the very margin of the Altamont moraine and are drained to the west into the Little

Sioux river. There are to the west of them no high protecting mounds, but, on the other hand, their marginal position subjected them to what is called overwash, deposits of sand and gravel from the edge of the retreating ice. This will account for the shallowness of Pelican lake and for the series of swamps and marshes by which in Clay county these lakes find outlet through Outlet creek to the Little Sioux river.

There are in Palo Alto county several other lakes of more or less interest. Elbow lake south of Ruthven is a little better than a marsh; Medium lake at Emmetsburg is permanent, and affords opportunity for boating and pleasure-seeking. Virgin lake and Silver lake, both on the west side of the county, are deeper, though not large, and are beautiful permanent features of the landscape. Rush lake, farther south, is of interest as the source of Lizard creek, to be presently described.

In Pocahontas county are no lakes of interest. Swan lake near Laurens, with native woods about its shores, once adorned with launches, a steamboat and all other minor craft, is waterless now even in this year of floods. Clear lake and Lizard lake also exist but in name.

Having thus disposed of the hill country and the lakes of our present territory we may now consider the simpler topography of the plains and meadows. These are conspicuously two-fold in their origin and position. We have, in the first place, the level of the general prairie. Of this nearly all Pocahontas county affords an illustration, nor less, large areas in Emmet and Palo Alto. About the town of Pocahontas, for instance, is a grass-grown level, unbroken for miles, and almost without drainage or slope in any direction. Where the lands are better drained the fields are yet flat, the streams long, crooked and shallow, sluggish and easily overflowed. In a general way the whole valley of the Des Moines river from Emmetsburg south is of this character. Compare again the table of levels, Emmetsburg 1234, Curlew 1222, Cylinder 1195, Rodman 1193, Whittemore 1207, West Bend 1197, Mallard 1198, Plover 1190, Rubens 1193, Gilmore 1207, etc. Here we have the indices of an almost absolute plain some fifteen or twenty miles wide and more than thirty long. Of course this plain is

not absolutely even; it is interrupted, in Palo Alto county especially, by scattered low knobs or ridges; in Pocahontas, less by such features and more by broader inequalities determining the far-reaching though all-imperfect drainage system. Such a level as this is known everywhere in these reports as a Wisconsin drift plain. In fact, our whole three counties may be regarded simply as such a plain sloping a little to the east, rather more to the south, cut diagonally into two almost equal parts by the Des Moines river, and encumbered to the west more or less extensively with irregular tumbled piles of the same constructive material, the groups and series of morainic hills. The lakes, for the most part, are simply undrained depressions amongst these hills.

But the river valley proper shows us a plain topography of yet a different character. On either side of the river, now chiefly on this side, now on that, is a peculiar gravel plain, abutting plump against the hills where these approach; below the level of the general plain and sharply divided even from this, where they mutually approach; distinct at once in structure as in position. This is no alluvial plain in the ordinary acceptance of the word, as might be at first surmised. Indeed, here is no alluvium at all resultant from the action of the present stream. Here is a plain, generally more than a mile in width, sometimes two or three, composed entirely, except a little organic matter at the top, of coarse water-laid sand, bowlders and gravels fifteen or twenty feet in depth, resting often on blue clay. If we study the course of the present stream we shall discover that it has indeed its own alluvium, its own alluvial plain, its flood-plain covered at high water, enriched by gifts of falling silt, but this is entirely a different matter. Over the gravel plain the river never, in its highest waters, sweeps at all; it never reaches to that lofty level. Yet, as just stated here are water-laid sands and gravels of wide extent. These valley plains are not the alluvium of our present stream; they are hardly to be reckoned the alluvium of any stream; they are rather the bottom of an ancient river that came down the valley occupying its total width in its sweeping flood, when the whole country, new-born, was taking shape

as we see it now. On this old river bottom, this gravel plain, stand Estherville, Graettinger, Wallingford, Osgood, part of Emmetsburg, Cylinder; the latter on an identical plain, though remote from the river. A fine view of this river-plain is obtained from the car-windows by those passing up and down the valley on the Rock Island railway. It is well seen from the morainic heights west of Estherville; it lies fair before the observer seen from the brow of the hill west of Osgood bridge; and, strangely enough, we traverse the same sort of a gravel, sandy plain, extending for some four miles north of the town of Cylinder, two or three miles in width. This plain has also the same origin as those by the Des Moines and represents an out-wash from the plateau of Fairfield and Independence townships. This plateau is a continuation of that seen in Kossuth county, its abrupt margin extending from the Crystal lake moraine in Hancock county around by Saint Benedict,Irvington, north of Whittemore and so into Palo Alto. This plateau lies thus between the Des Moines and Iowa rivers near their origins, and rises to a height of something like one hundred feet above the general level, the highest point between Algona and Whittemore.

Following is given the elevation of several towns in the area under discussion. The data were obtained from Gannett's dictionary of altitudes in the United States:

TABLE OF ALTITUDES.

Estherville	1,298	Rodman	1,193
Armstrong	1,237	West Bend	1,197
Emmetsburg	1,234	Plover	1,190
Crippen	1,166	Rolfe	1,160
Ruthven	1,435	Gilmore City	1,207
Cylinder	1,195	Rubens	1,193
Ayrshire	1,293	Havelock	1,227
Curlew	1,222	Laurens	1,307
Mallard	1,198	Fonda	1,232

The margin of the above mentioned plateau in Palo Alto as in Kossuth has been generally well drained so that the topography is unusually broken as the plateau breaks off to the plain.

Thus the north part of Fairfield township is well drained, although representing the Wisconsin plain. Considerations such as these lead us easily and naturally to our next topic.

DRAINAGE.

Des Moines river.—The valley of the Des Moines river in two branches constitutes the principal drainage channel of the territory we study. That drainage is determined by topography is proverbial in northwest Iowa. And so the Des Moines, especially its western branch, occupies, in large measure, a rather wide, constructional depression, first formed and excavated by glacial drainage, then partially filled again, as we have seen. This West Des Moines is, at the ordinary stage, a fine clear stream, of great service, both as a drain and for water supply, and its course southward is very interesting to one who will study determining causes. Taking rise in Minnesota it enters Iowa almost exactly at the northwest corner of Emmet county, making its way amid morainic hills, cutting through their opposing ridges it reaches the Wisconsin plain in the neighborhood of Estherville. Here, however, its course is still controlled by the moraine; the high, abundant, hills of western Emmet county guide the river to the east, nor less those of western Palo Alto, until immediately south of Emmetsburg morainic ridges of rather low degree divert its course and send the stream eastward, finally in Nevada township directly east, only to encounter south of Rodman the West Bend series of hills through which the stream makes its tortuous way to enter Humboldt and Pocahontas counties almost simultaneously, following in zigzag fashion the line between the two; joins Beaver creek, which may represent an old-time channel, and finally enters at Bradgate, about one mile east of Pocahontas county line, the rock-walled conduit of some preglacial water. It is even possible that Beaver creek may represent part of the same preglacial, i. e., pre-Wisconsin, stream, and this may be a remnant of what is now the Little Sioux, whose course has been so strangely shunted by the Altamont in Clay and Buena Vista counties.* At any rate, we are beginning to see

*See of this series Vol. XII, p. 334, *et seq.*

that the pre-Wisconsin drainage of all this part of Iowa was not very different in direction, at least, from that which obtains today. Great ridges of older drift are still in evidence, which have for ages been watersheds; the Wisconsin simply threw these less forceful streams into confusion. The uncertain course of the Des Moines across these prairies is apparent when one notes the often slight character of the obstacle by which the stream has been deflected; some low swell of drift, of sand and gravel, as in section 33 of Nevada township, Palo Alto county, or in section 32 of Fern Valley township in the same county. Indeed, the course of the river is scarcely yet determined. In time of flood the river, south of Emmetsburg, leaves in part its channel in section 2 of Great Oak township, passes directly south around an island of morainic knobs in sections 12 and 13, and finally joins the main current again in section 20 of Nevada township. In fact, the whole of Ellington township and part of West Bend is simply a confused field of low, irregular hills and swamps where it would seem that a river might cut through at any time in one place as well as another. West Bend, so named because the valley of the river was settled by immigration from the south, and for men coming from the south the river here turned west, West Bend is, after all, truly historic in its naming. We must remember that our assumed ice sheet retreated northward; the excavation of all stream-channels now in service proceeded pari-passu, with equal pace. Beginning, for instance, with the stony channel in Humboldt county, the conduit of the Des Moines was determined northward a little at a time; and any slight obstacle, no doubt, was at first sufficient to determine the direction of the current. This will explain the peculiar winding of the river in these townships named. The current returns again and again upon itself; surely no such crooked channel is elsewhere represented on the maps of Iowa. For this reason, although a drainage channel of prime importance, the river is here singularly inefficient, and the problem of those who would cultivate these naturally undrained meadows is difficult indeed.

The tributaries of the Des Moines in this part of Iowa are School-section creek, draining the western part of Emmet

county, cutting down to the level of the river through a chasm of remarkable depth, of wild abrupt, picturesque beauty, but not yet efficient for the remoter sections of the basin in which it rises; Jack creek, the outlet of Swan lake and ordinarily simply a creeping, crooked prairie stream, draining imperfectly a township of the same name; Cylinder creek, a stream of the same sort, draining pretty well the two northeastern townships of Palo Alto county and receiving as a contribution from the west the waters of the unwilling outlet of Medium lake, a body which seems formerly to have sent its surplus waters southward directly to the Des Moines, across the plat of the present city of Emmetsburg; the outlet of Silver lake, Willow creek, which has effected considerable erosion and affords in ordinary seasons good drainage for the farms of Great Oak township; Beaver creek and Pilot creek, which, rising in Palo Alto county drain some of the finest of farms in the vicinity of Curlew and Mallard and become efficient streams in the northeast township of Pocahontas county. The Lizards which in manifold branches spread over nearly the whole of the county last named, deserve a special sentence. Lizard creek, as a stream of some dignity and recognized importance, enters the Des Moines in Webster county, but in Pocahontas county it consists of three principal branches with many secondary, sometimes inter-communicating marshes and sloughs. These branches in many places lie upon the prairie rather than drain it. Except in the case of the North Lizard, and far down in its course, erosion is almost none. Here and there the county supervisors have taken the matter in hand and have cut a broad ditch for the impotent, channel-less stream. As central Pocahontas county is a typical Wisconsin plain, so the Lizard creeks are typical prairie streams. Fortunately a deep channel of the Des Moines is not very far away, with a fall to the north of the Lizard of something like two hundred feet, so that the art of the engineer will no doubt one day amply supplement nature's unfinished work for Pocahontas county.

Cedar creek with two principal branches is an important stream in the western part of Pocahontas. It rises in the marshy fields north of Laurens and affords to the townships it

passes fair drainage. Cedar township, especially, is well drained.

The East Des Moines, although a fine perennial stream, is of importance in this discussion only as affecting the northeastern townships of Emmet county. Even here, such is the morainic character of the country that artificial drainage is everywhere resorted to.

In ordinary seasons the drainage of all this section of Iowa would seem a matter of no especial difficulty. Within the last ten years thousands of acres of lowland have been brought into cultivation; but in seasons of unusual rain the problem of speedy removal of surplus storm-water becomes more serious.

STRATIGRAPHY.

From the preceding description of these counties it is easily inferred that the stratigraphy, or geologic structure of this part of Iowa, so far as exposed to ordinary view, is extremely simple. The drift is indeed susceptible of some classification, but the student seldom finds it in sections undisturbed. Erosion valleys, by the very nature of the case, are less satisfactory. These looser deposits become mingled; they are always "in place;" i.e., while a transported indurated rock is identifiable as such, the materials of the drift lose their identity no sooner they leave their proper horizon. In other words, while the stratification of the drift when undisturbed is evident enough, yet to identify the elements of the several strata once weathered or eroded requires discrimination of the most discerning sort. The materials from which the successive drift sheets have been built up are much the same; yet there are differences, more striking and more numerous doubtless by far than our science is now prepared to realize. However, even erosion valleys often serve, when the shifting current uncovers a fresh surface or undermines a slipping hillside. Other than this the student of stratigraphy relies upon the glimpses offered by artificial excavations of various sorts, the grading of the highway, the cutting of the railway through a mound or hill, the sinking of farmers' wells.

One outcrop of the older rock also strangely enough comes to light within our present limit so that our synoptical table is more extended than was to be expected:

SYNOPTICAL TABLE.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvium.
		Glacial.	Wisconsin Gravels. Wisconsin Clay.
			Kansan.
			Pre-Kansan sands and gravels.
Paleozoic.	Carboniferous.	Lower Carboniferous.	St. Louis.

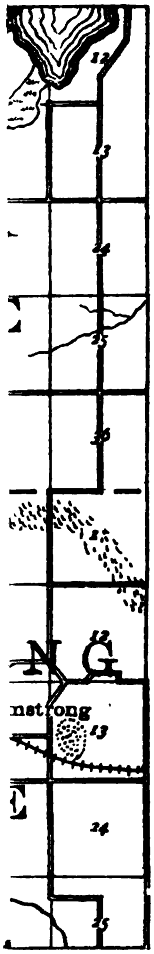
GEOLOGICAL FORMATIONS.

Pleistocene System.

The Pleistocene deposits,here as elsewhere in northern Iowa, consist entirely of sheets of clay, gravel, sand, or of these inextricably mingled together. In fact a pure clay is probably nowhere to be found within our present limits; so that we may say that our Quaternary or Pleistocene deposits here are wholly drift, mingled clay and pebbles or bowlders, or beds of gravelly sand.

ALLUVIUM.

By this term is indicated the fine, usually black, soil ordinarily present along the banks of rivers and streams in prairie regions, which evidently owes its position as well as character to the sorting agencies of water. Ordinarily it is a fine, black silt, sometimes heavy with fine sand; and represents the latest



IOWA GEOLOGICAL SURVEY

MAP OF THE

SUPERFICIAL DEPOSITS

OF

EMMET

COUNTY,

IOWA.

BY

T. H. MACBRIDE.

1905.

Scale $\frac{1}{125000}$

or farthest deposition from waters laden with the products of erosion. In our newer valleys the amount of such material is inconsiderable; nevertheless there is some of it discernible by all the principal streams, as the branches of the Des Moines, where occasionally a wide, flat meadow is made up of alluvial soils that rest thinly upon beds of river sands and gravel. Sometimes it has accumulated to the depth of several feet and shows black banks in presence of most recent erosion. The amount of this material is, however, in the present case too small to admit of representation on the map.

WISCONSIN STAGE.

Wisconsin gravels.—The deposits so named are the immediate effect of the outpouring of the waters accompanying the melting and retreat of the Wisconsin ice. As the face of the ice cliff moved northward the floods of water seem to have covered the country and the gravel and sand with which the streams were charged were deposited everywhere; especially, of course, in the forming valleys and channels of drainage. Sometimes these channels were no doubt on or in the ice itself so that gravel deposits may, and often do, now appear far out of the way of any present drainage system of any sort whatever; in isolated mounds, on the flanks of hills, in low ridges athwart what were otherwise a level plain. As already indicated in the discussion of topography, the valley-plain of the West Des Moines river is a gravel plain, all gravel of varying depth and width, from the Minnesota line or near it south to Humboldt county. At Estherville and at other points this gravel is worked by the railways for ballast-construction, and from the city named thousands of car-loads have been transported in this way to various parts of the state. The beautiful situation of the town (see plate IV) is due wholly to this unique deposit. The city is built on the gravel plain. One ascends to the typical drift as he passes east out along any of the principal streets. In many places one may see the distinction by merely standing in the street and looking east.

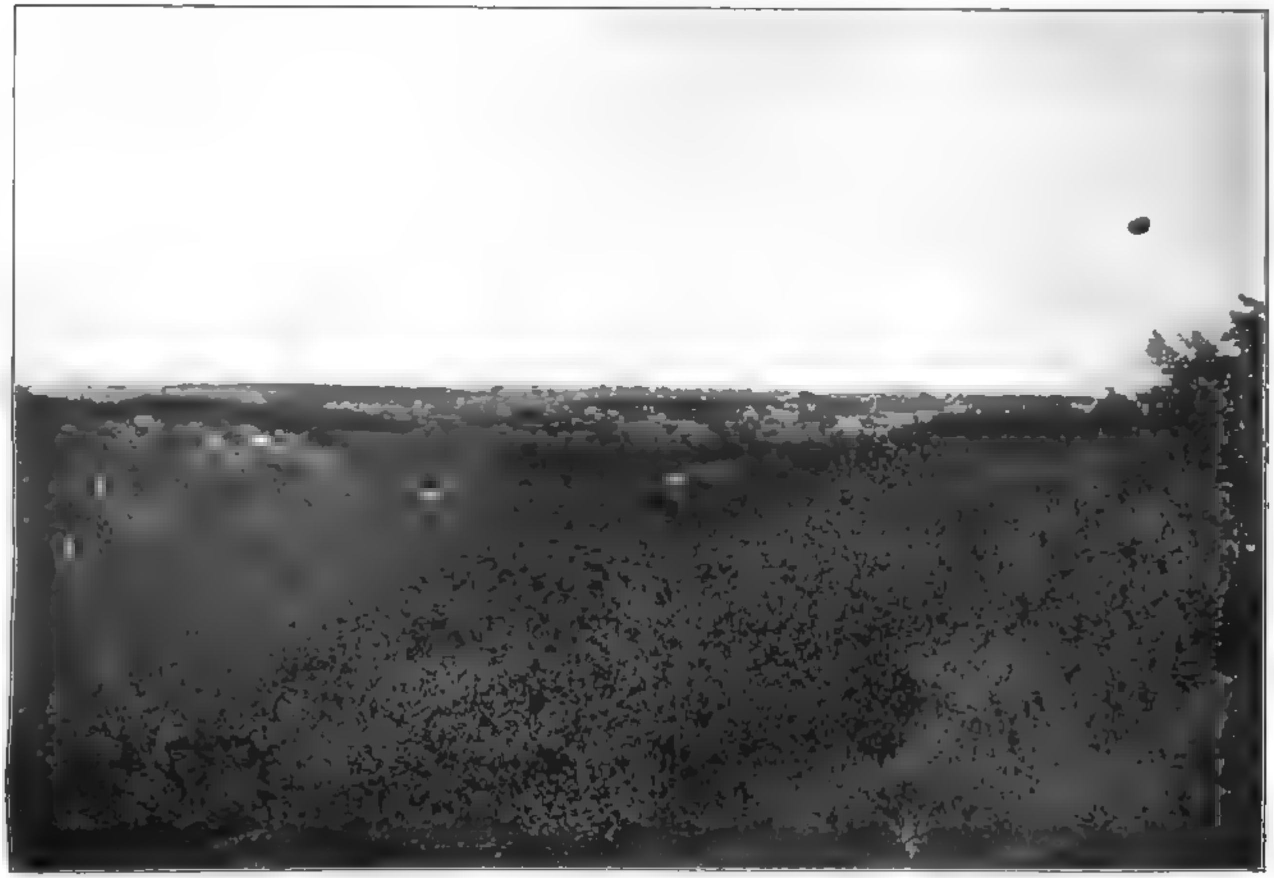


Plate IV. View of the town of Estherville, and the prevailing topography of the Wisconsin drift.

At the bridge across the Des Moines in section 28, township 100 north, range 34 west, the gravel is piled in such a way as to give the observer a fair idea of the immense erosion changes that once went on in what we now term the valley of the river. Here the gravel on either side of the river is discoverable high up above the ordinary plain, fifty or sixty feet; lodged against the banks of drift. Between lies a half mile or more of gravel plain perfectly solid and flat, the bottom of the ancient glacial river that swept this way and eroded the valley as we see it, beginning away up on the level where now occur the highest deposits of these singular water-marks. The present stream is as nothing when compared to that earlier river. The Des Moines river in this year of 1903 is described as high beyond the previous experience of observers, and yet the Des Moines river by no means covers this gravel plain. The present stream has its own flood plain which in times of freshet it may cover or erode, but this old time valley owns no relationship to the present river. One might suppose that the action of the earlier, larger, current continued not very long; but we must reflect that the erosion force in this its upper channel was limited by the work that must be done arther south and east, where the indurated Paleozoic formations were encountered and set bars to the agents of erosion as at this day. The result is that the gravels of that older river lie in these upper stretches largely undisturbed, slow-mouldering with the lapse of centuries.

When we come to investigate the composition of the gravel trains we discover, first of all, the evidence of the mode of their deposition. No better sections need be wished of the entire deposit than those encountered at Estherville. Here one may easily see the sorting cross-bedding resultant from the water currents that once swept the stony debris on and down. But the materials themselves are of every imaginable source; i. e., one may find samples of rock of almost every description of all sizes, from merest pebbles to stones weighing hundreds of pounds. Some of these pebbles are of great age as such; have long been buried, subject to the slow action of waters, filtering, bearing all sorts of solvents in solution. Such pebbles no longer hold together as rock at all, but crumble no sooner exposed to light

and dryness, may be picked from the bank and crushed in the fingers. Through large gray bowlders the steam shovel passes as through sand, and such sections may be commonly observed. These were doubtless, some of them already long constituent parts of the older Buchanan gravels which the Wisconsin ice in these latitudes so generally swept away. Possibly the larger part of these vast recent deposits consist of but a resorting of those older piles and trains laid down by the waters of the Kansan so long ago. Nay; perhaps some of the earlier gravel, even in these river valleys still lies in place here on the blue clay that stretches everywhere beneath all surface deposits in these

FIG. 16. The gravel pit of the Minneapolis & St. Louis railway, Estherville, Iowa. This illustration shows in a marked degree the characteristic cross-bedding of glacial gravels.

regions. Thus if anyone will closely scan the exposed wall of gravel in the excavations south of Estherville he will easily discover that the lower portions of the exposure are different, strikingly different, from the upper, overlying part. The wall

stands up largely because of these differences. Above, the gravel is more loose, fresher and evidently more recent, judging from appearance; below, the material is imperfectly stratified, often stained with iron, deep brown sometimes, the pebbles and bowlders more or less cemented together and associated with concretionary nodules of impure hematite. The line of demarcation is not well defined, but is sometimes quite evident. One is inevitably led to conclude that the lower gravels are here older than the upper.

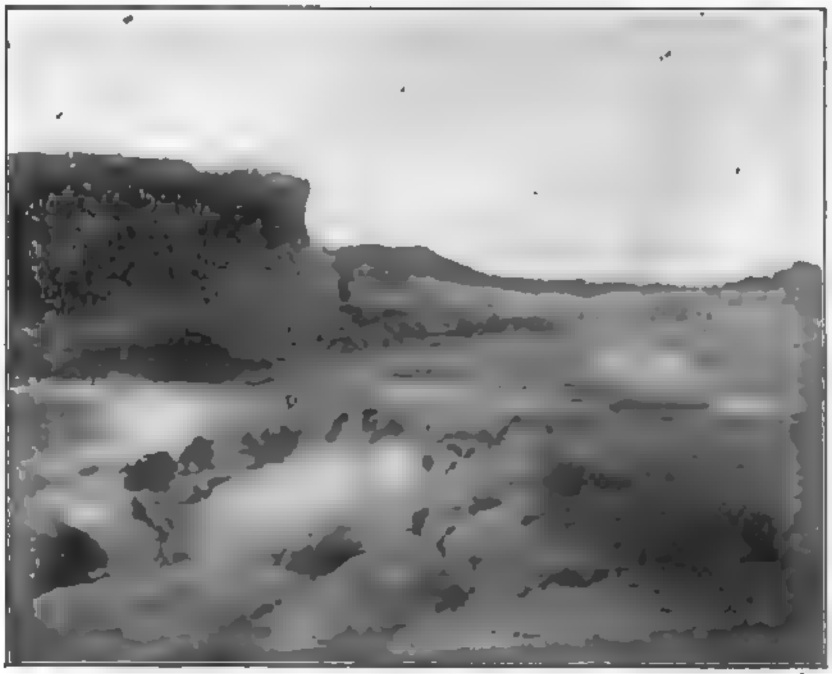


FIG. 17. The blue clay—eroded by the drainage stream issuing from the gravel pit of the Minneapolis & St. Louis railway, near Estherville, Iowa.

But this is not all. In the gravel pits operated by the Minneapolis and St. Louis railway near the same city of Estherville, especially at the extreme south of this artificial exposure, storm-water erosion has supplemented the artificial excavation to the complete uncovering of the old blue clay. A finer display of this was never seen. Resting directly upon this bed of

blue clay is the same more or less indurated, brownish gravel seen in the other excavations, while further north appears the typical sands and gravels of the Wisconsin age.

However we may name these lower gravel strata, the wide distribution of the Wisconsin subwash and overwash is indisputable. Not only by the river, as here, but, as noted, far away from streams now flowing or even the possibility of streams, piles of water-laid sand and gravel surprise the traveler. At Ruthven there is abundance of this material in the lowland west of the city, nor less on the top of the hill in the city itself near the Rock Island station. In many cases these gravel deposits rest unmistakably on the country drift, so that there can be no question as to their relative age.

The Wisconsin drift.—This is the common surface drift or pebble clay of all this northwestern country. It has been often described in these reports and is generally easy of recognition; strongly calcareous, it is usually white or whitish when dry, though sometimes yellowish or buff colored. Ordinarily it is covered deep by rich, black surface soil and visible only where uncovered by erosion or some sort of artificial excavation. However, exposures are sufficiently abundant. Throughout the entire intra-morainic territory as sketched in these reports, the characteristic color, the flat, limestone pebbles and small, angular bowlders, often of the same material, newly planed, mark every hillside road or railway cut. The abundant lime, whether in form of finest dust or as pebbles and bits of limestone rock, forms the most patent characteristic of the deposit. To the west this drift passes over into something older, but in color and appearance often but slightly different. The reader may compare earlier volumes of this series of reports; this may be subject of future discourse. But in our present territory the Wisconsin drift is well defined, remarkable, chiefly, for its thinness as a deposit. In fact, the relation of this deposit to underlying strata in these marginal counties merits closest scrutiny. Over the larger part of our area, over all, if well diggers, almost our only source of information, are to be believed, true Wisconsin drift does not average more than fifteen feet in thickness. Doubtless in western Palo Alto and Emmet counties, on the morainic hills, the depth is often

great; but on the ordinary Wisconsin plain the depth is quoted never to exceed twenty-five feet, and often no more than five or six. In the moraines are great piles of it, as one may often see in sections where, in our rectangular road-making, we must need cut through a hill of greater or less extent, but everywhere else the depth is comparatively small. Such exposures as were noticed showing Wisconsin drift above blue clay were not inconsistent with well-reports. An outcrop of the older formation occurs immediately west of the Osgood bridge over the Des Moines. Here the thickness of the later drift does not exceed twenty-five feet. The question of an earlier and a later Wisconsin for this part of Iowa remains for future decision.

KANSAN STAGE.

Buchanan gravels.—Old gravels of Kansan age, called in Iowa Buchanan gravels, were reported in an earlier sketch by the present author.* The outcrop appears overlying the Saint Louis limestone in the Gilmore quarry. In addition to this, the older gravels already described in the pits south of Estherville may with more or less confidence be here referred. There are other exposures of old material. Indeed, it seems as if it may be looked for almost anywhere as a bottom deposit of what has been here denominated the gravel plain. Something of the older gravel, for instance, appears along Cylinder creek as it emerges from the plateau in Fairfield township of Palo Alto county. It must be admitted that in exposures so far seen the gravels here in question are not well delimited above, but their uniform occurrence in direct contact with the blue clay would seem to justify the present provisional reference.

The Kansan drift.—This widespread formation is in evidence in every part of the territory we now describe. Not a deep well has been successfully opened but "goes through the blue clay." Everywhere the gravel of the valley is reported resting on the blue clay, and, as above noted, the report may be easily confirmed by present exposures. This blue clay is decidedly marked both in constitution, color and general appearance as to be unmistakable, so that we may assume as correct its gen-

*See Vol. XI, p. 188 of the present series.

eral identification. It is exceedingly tough and endures erosion, almost as so much rock. The eroded surface looks like eroded rock. The matrix is a fine-grained, compact clay, but in this is commingled sand, pebbles, bowlders of various sizes and shapes, in the strangest confusion. It is difficult to imagine how such a mass has ever come into place. It has the appearance of a more than half-dried paste, stiffened and compressed during the long centuries by vast superincumbent weight. No other formation on the face of the earth compares with it. There are in the older strata slates and shales and clays, soft masses that have endured enormous pressure and so been modified and changed, but they are not like this; this is a glacial clay, unjointed, unfissured, unwedgable, unblastable, the unyielding foundation of all our surface soils, the unperforate, impervious cap of all our subterranean waters.

The thickness of this deposit is very far from uniform. Reports of well diggers go as low as ten feet; but more frequently from one to three hundred feet is the range of experience. In Emmet county, in Estherville township, the well of Mr. McKay went three hundred feet in blue clay; but this is on a high ridge where some of the pre-Wisconsin topography probably still persists. The older blue clay was no doubt subject to erosion for centuries before the later glaciers came upon it to still further shave away its upper surface. The inequality in thickness is probably thus to be explained. Underneath the blue clay is a widespread couche or bed of gravel and sand, and often more clay below that, so that there is evidently another drift sheet below the famous clay. On the farm of Mr. Lardell of Emmet county is a well two hundred and seventy-five feet deep. The record given by the well-digger is:

To the blue clay	20 feet
Blue clay	130 feet
Gravel, with water	3-4 feet
Blue clay	40 feet
Black muck	2-3 feet
Yellow sand	80 feet

This "yellow sand" is evidently below a former vegetation-bearing surface. The muck represents organic stuff, plant and animal remains in a state of partial oxidation or decomposi-

tion. This decomposing matter sometimes sets free inflammable gases in considerable quantity, and such gases caught under the clay find vent only as the covering is pierced. The Burnett well, near Swan lake, emitted an inflammable gas, and when this was ignited "it burned for three months." More commonly the gases thus set free are not inflammable; they are either ordinary air that has been caught and so imprisoned, or

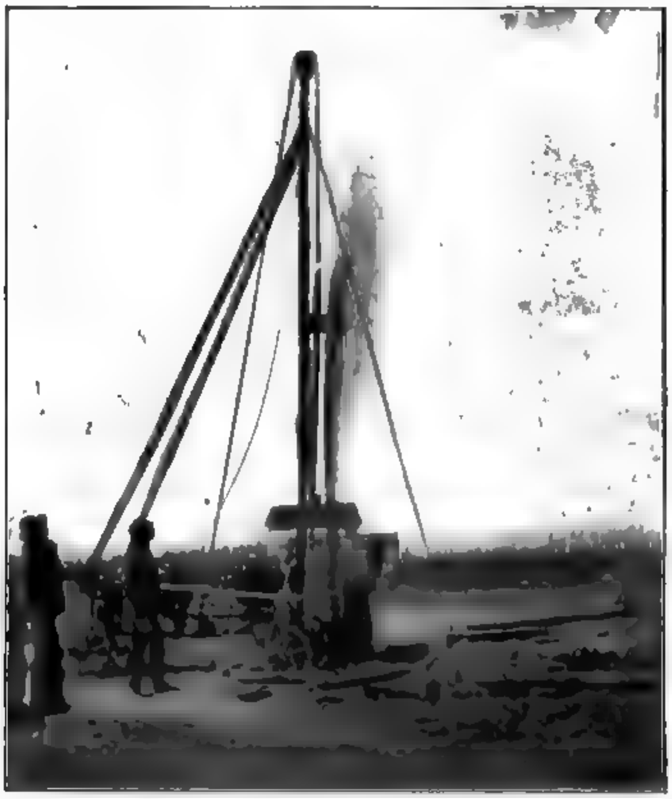


Fig. 18. View of the Wier well showing the escaping gas when a pocket of gas-bearing sand in the drift was penetrated. Emmet township, in Emmet county.

they consist largely of choke damp, carbonic acid gas, another result of the decomposition of organic stuff in places destitute of available oxygen. Thus, Mr. Grems, a well-digger at Swan lake, asserts that all the wells in Center township, from Ryan lake north, are blowing wells when first the blue clay is

pierced. The well on the farm of Mr. George Weir, in Emmet township, blew for days in such a fashion as to stop all proceedings. Pebbles of considerable size, and pieces of wood, were cast high into the air, "more than one hundred feet." By the kindness of Mr. C. C. Stover, of Estherville, we are able to offer here a cut showing the Weir well in action. Figure 18.

The blue clay, therefore, however discovered, is one of the most interesting formations in Iowa. It deserves thorough and widely extended study, and stands closely related to the water supply of the entire state.

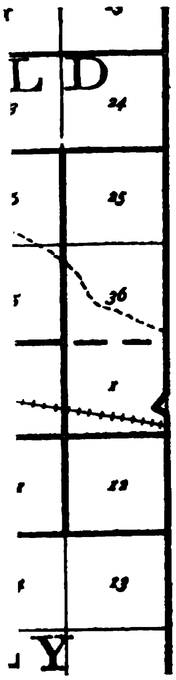
PRE-KANSAN STAGE.

Pre-Kansan sands and gravels—These have been already referred to in the preceding section. Our only knowledge of them in this region comes as a result of well construction. We are indebted to Mr. R. I. Cratty for the following log of a 500-foot well recently drilled at Ringsted:

7.	Surface drift	12 feet
6.	Blue clay	138 feet
5.	Gray or bluish sand	10 feet
4.	Yellow sand	38 feet
3.	Shale, black and white	164 feet
2.	Blue shale	2 feet
1.	Limestone	136 feet

The porous beds form the universal aquifer or water-couche under the blue clay; sometimes directly, sometimes with the intervention of an old time land-surface, with muck, etc., under the blue clay; in case of the McKay well, already mentioned, occurs sixty-five feet of clean white sand"! This is not only of itself remarkable, but recalls an exposure of similar material in the banks of the river a few miles northwest of Humboldt, in Humboldt county. These sands may represent a pre-Pleistocene formation, possibly Cretaceous, and further reports of their distribution may be awaited with interest.

Since the boring of most wells stops no sooner than a water-bearing gravel is reached, we have no means of determining the the amount or depth of the pre-Kansan in our present territory.

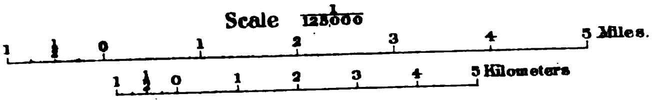


BY

T.H.MACBRIDE

1905.

Scale $\frac{1}{125000}$



LEGEND

GEOLOGICAL FORMATIONS

ALLUVIAL DEPOSITS

"Twenty feet in the gravel" is, however, a not infrequent description. In Pocahontas county the drift layers of all ages appear to be thinner; the blue clay is quoted at thirty and forty feet, and the subjacent gravels it would seem, sometimes fail entirely. Wells are sunk in limestone rock.

Carboniferous System.

SAINT LOUIS LIMESTONE.

The only outcropping of indurated rock in the region we study is found in Pocahontas county. This exposure has already been made the subject of comment in these reports and the present review of the case can offer no new facts or detail.* The exposure in question is limited to a very narrow area, one hundred acres or less, and even then is not a natural exposure. Where quarried the rock is covered by soil and drift to a depth of several feet, although a few rods further south rock in place is struck by the passing plough. The quarry occupies the place of a former sink-hole as described in the report cited; the upper strata of the rock are marked by fissures long subject to erosion by descending floods of water, and the quarry shows natural walls of cross-bedded limestone. In these wet seasons, work in the quarry is much hindered by water, which fills the pit in a night, but presently disappears again by subterranean drainage.

Above the limestone, between the limestone and the drift, occurs in limited measure, on the west side of the present opening, a deposit of peculiar, fine-grained, non-calcareous, reddish clay. The stratigraphical relationship of this substance is not known. It is interesting in its position and if in quantity would possess high economic value; it is so very pure and uniform. That such substance has been reached by those who in Pocahontas county sink their wells to the limestone in various places is nowhere reported. This clay may represent a member of the Cretaceous system.

* See of this series Vol. XI, pp. 131-133.

ECONOMIC PRODUCTS.

Clay.

The economic celebrity of these counties will, in the future as in the past, rest rather upon the extreme fertility of the soil and its adaptation to varied agriculture, rather upon this than upon resources of special type such as occur in the regions affording ore and coal. Even the manufacture of tile and brick is much handicapped by the occurrence of a large percentage of calcareous pebbles inextricably mingled with the ordinarily accessible beds of clays. Many efforts are making in various places, if possible to obviate this difficulty. At Armstrong, Messrs. Robinson & Stewart, although their work is yet somewhat in the experimental stage, will manufacture this year some 300,000 brick and about the same number of tile. The clay used is from a peaty slough a short distance north of the works. It is reasonably free from the lime pebbles, but still gives so much trouble as to suggest plans for their elimination. This is the only attempt at present in Emmet county toward the prosecution of the clay industry. In Palo Alto county there is at present, so far as could be learned, no brick or tile kiln at all.

At Fonda in southwestern Pocahontas county the Straight Brothers have been very successful in handling the same pebbly Wisconsin clay. They use a rotating screen and so eliminate from the dry material pebbles of all and every sort. The dump behind the screen-house reveals in a surprising way the nature of the difficulty everywhere encountered in the making of brick in northwestern Iowa.

By the means adopted, however, Straight Brothers are making excellent tile at the rate of about one million per annum. Some shale from Fort Dodge is imported and mixed with the screened clay, and such brick is said to excel that made at Fort Dodge, from shale or Carboniferous clay alone.

At Rolfe, Messrs. Nelson and Dawson have recently undertaken the manufacture of tile. The material used is the same as that sought elsewhere, a Wisconsin clay which has been somewhat sorted by the action of water, that is fine silt; here partial alluvium. The pit shows rather uneven material, but the product is quite good; some of it excellent. It is here proposed to separate the pebbles by a process of washing, and plans are maturing for such an experiment. The present capacity is 700,000 tile per year; no brick. In all these cases coal is the fuel used, and this is brought from Des Moines. But with all the disadvantages, it appears to be far cheaper to import fuel and manufacture on the ground than to import the vast quantity of tile which for this undrained territory is an absolute necessity, and where for years to come the demand will outrun all probable local supply. For farm drainage even large sizes of tile are demanded and pipes fifteen and sixteen inches in diameter are going into the marshes of these counties.

Since the report on Clay county was written a bed of almost pebbleless clay has been discovered a mile or so northeast of Spencer. From this, although its extent is at present unascertained, great results are expected. So far as examined the tile are excellent and the clay promises well. This clay lies in a flat, undrained field, higher than the gravel plain and is no doubt a deposit from water. It is not loess but represents the result of the slow subsidence of fine silt during a long course of years. Such deposits are to be expected everywhere where similar conditions obtain. The gravel plain from Estherville south to Emmetsburg was formed under conditions precisely similar to those which gave rise to the gravel plain at Spencer; so that deposits of similar clay may be hopefully looked for pretty well up toward the general country level, but in the vicinity of the great drainage valleys. Such deposits are likely to be discovered by the ditcher. As this is written there are rumors that some such beds have been discovered not far from Estherville. *

* Investigation shows the material in use at Estherville to be the common blue clay underlying the whole country, and effort is making to free the clay from pebbles and bowlders. June, 1905.

Stone.

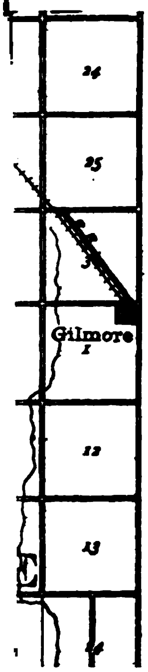
The one stone quarry of the three counties, that near Gilmore in Pocahontas county, is in constant use, but the amount of rock taken out is nothing like so great as in former years. The rock is well bedded, comes out in fine blocks for all sorts of range work, but has, after all, only a local demand. The product last year was eight hundred and seventy cords. Quarrying for two years has been hindered much by surface water. The location is low, a former marsh, in fact, and heavy rains fill all the excavations with water. This, however, disappears presently by the marvelous subterranean drainage characteristic of this part of Iowa. The Gilmore rock is very rich in lime. According to reports some samples show 99.64 per cent lime. A large set of lime kilns was once in operation here, but for some reason the lime industry has been abandoned.

Gravels.

Among the several natural economic resources of this region the vast supplies of gravel found, as stated, along all streams and not infrequently remote even from the water-courses, seem deserving of special mention. These gravels are today carried by hundreds of car-loads to be used as ballast along the great railway lines of the Northwest. Nor is such material less serviceable in the localities where found. Gravel makes excellent streets; witness those of Estherville; excellent country highways; excellent causeways across marsh and flat as every traveler along the valley of the Des Moines will gratefully testify. The old glacial gravels of northern Iowa are the sure promise of good public roads.

Water Supply.

Through two of the counties here studied, the West Fork of the Des Moines river passing, affords a perennial water supply. The general drainage system of the country whether natural or



T. H. MACBRIDE.

1905.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

WISCONSIN DRIFT

INDUSTRIES

artificial is also in a measure serviceable. Beaver creek, Lizard creek and Cedar creek in Pocahontas county are said to be perennial streams. But water of excellent quality is everywhere so surely accessible in wells of moderate depth that, for serving the purposes of the people, streams and lakes are hardly regarded. In many places, as on the gravel river-plains, water is obtained by the so-called "drive wells." This is true also of the vicinity of Cylinder and north. Wells of twenty to thirty feet in depth and inexhaustible are reported from Ringsted, Mallard, Curlew and other places. In most cases, however, the wells are deeper, ranging from eighty to four hundred feet. The city water supply at Estherville is from springs coming out on the blue clay near the Des Moines river. Similar water doubtless fills the wells in the gravel at Graettinger and at Emmetsburg. Fonda has a deep well with water of excellent quality.

Fuel Supply.

Residents of these counties rely chiefly for fuel upon outside sources of supply. There is some native wood; every farmer has now a grove; so that wood is comparatively cheap. In some places vast beds of peat occur, as at Ruthven in Palo Alto county, but Iowa peat has only in rarest cases been put to practical use.

ACKNOWLEDGMENTS.

In the preparation of these reports the author has enjoyed the assistance of many people in every part of the counties traversed. Mr. C. C. Stover was especially helpful at Estherville. Mr. Jackson, of the Watson Land Co. at Emmetsburg, gave personal assistance in the work of the survey. To Mr. R. I. Cratty of Armstrong we are indebted both for many courtesies and for the accompanying Forestry notes which are the result of his long study of the flora of the upper Des Moines valley. To Professor Calvin, the Director of the Survey, the author is under constant obligation for counsel and personal assistance.

FORESTRY NOTES FOR EMMET COUNTY.

BY R. I. CRATTY.

General Discussion.

To one who has spent much of his life in a forest region, our treeless western prairies present a picture which, though interesting at first, at length loses much of its attractiveness because of the monotonous landscape. When this portion of Iowa was plowed and furrowed by the ice fields which covered the region during the Glacial epoch, the retreating ice left its load of clay and sand and gravel in low ranges of hills which in our day help somewhat to relieve this monotony, but excepting these morainic hills and the lake beds, the ever varying topography is usually the result of erosion. Though the face of a country vary ever so much in the character of its surface, and in its carpet of green grass, adorned with beautiful flowers, still there is something lacking if the trees, those noblest examples of Nature's handiwork in the vegetable world, are wanting.

However well this region may have been covered by an arboreal vegetation previous to the period of the Wisconsin drift, its reforestation after the ice disappeared has been very slow. Among the many causes which have united to produce the result may be enumerated the hot, drying southwest winds of autumn, quite common in western Iowa some years ago; and since man's advent upon the scene, the prairie fires. In this portion of the state land sloping to the southwest is usually devoid of native timber unless protected in that direction by high bluffs, or some considerable body of water, which would modify the effect of the hot, dry winds. A northeast slope, other conditions not being wanting, is an ideal one with us for native timber, as well as for orchards and artificial groves. Until recently the prairies were covered every season with a luxuriant growth of native grasses, and were very often burned over by the Indians, and in later years by the white hunters and settlers. These

fires usually occurred in late autumn or early winter when the prevailing strong winds were from the west or northwest, and this is at least one reason why our native timber is mostly found on the south or east side of lakes and streams. When it does occur on the west or north it is usually a fact that the forest line is protected in that direction by bluffs with a scanty covering of grass, or by deep marshes. It may be observed also that no timber except a few small willows, is found along the smaller streams flowing through our more level regions, which, though capable of furnishing the necessary conditions of soil and moisture, nevertheless could not furnish protection from the prairie fires.

The area of native timber in this county is quite small, much the larger body being found along the West Fork of the Des Moines river, west and north of Estherville. There are also several smaller bodies, the larger of which are along the East Fork of the Des Moines in Armstrong Grove township, and along the shore of Iowa lake. Now that the days of the prairie fires are ended, a young growth of timber, mostly ash, box-elder and willow, is gradually fringing both banks of our rivers, and if man does not interfere, our forest area will surely increase.

A great amount of the best timber in this region was cut down by the early settlers for fuel or for building purposes, some of it being sawed into lumber by sawmills which have long since disappeared.

Since the advent of the railroad, bringing fuel and lumber, this wholesale destruction of our best timber has almost ceased, and a fine young growth, if given sufficient protection, will in time do much to restore the former conditions. The habit of too closely pasturing our native woods can not be too severely condemned, as, where the humus and undergrowth are destroyed by the tramping of cattle, the hot, drying weather of autumn frequently causes the death of many of our native trees. By retaining this leaf mould and undergrowth, thus preventing too rapid evaporation, and a judicious cutting of the older timber for use, there is no reason why our woods should not gradually improve. Fortunately, our best timber is situated on land unsuitable for cultivation, and thus at least

one temptation is lacking to remove it, and it is sincerely hoped that the owners of these tracts will use all reasonable efforts to preserve and improve the present condition of what is left.

The most valuable of our trees are the two species of oak, the bur oak and red oak, the white and the slippery elm, the hard and soft maple, one ash, one hickory, the basswood, the hackberry, the black walnut and the cottonwood. Besides these there are numerous smaller trees and shrubs. There are also several species of trees common in cultivation such as the cottonwood, lombardy poplar, white willow and several kinds of evergreen.

Throughout this prairie region there are numerous artificial groves which add much to the beauty of the landscape, and there is no reason why every country home should not be surrounded with a beautiful grove of trees to furnish a shelter from the severe winds and the snows of winter, and in summer to delight us with cooling shade, and furnish a safe home for our feathered friends, that they may come and dwell among us and sing to us their songs of joy and gladness as they build their nests and rear their young.

List of Trees.

The following list of the trees and shrubby plants of Emmet county, systematically arranged, is also believed to be nearly complete for the bordering counties as well. The number of species is comparatively small, but this may be partially accounted for by the fact that this region was entirely covered by the Wisconsin drift, a much later geological formation than is found in the southern and eastern portions of the state, and one which gives us little variation in the character of surface and soil.

PINACEÆ.

1. *Juniperus virginiana* L. Red Cedar. This is the only evergreen native to this portion of Iowa, and is found sparingly on the bluffs around the lakes. Most of the trees have been cut for fence posts for which purpose they furnish our most

durable timber. This tree flourishes well in our prairie soil and makes a rapid growth. It may be used to advantage as a windbreak as well as for ornamental purposes. The dark green of its foliage contrasts very pleasingly with that of the surround ing deciduous trees. Besides it has economic value for the purpose mentioned and there is no reason why farmers should not raise their own fence posts.

JUGLANDACEÆ.

2. *Juglans nigra* L. Black Walnut. This very valuable tree was once quite common in low woods. It is at present quite scarce in a wild state, having been made into rails and used for fuel by the early settlers; and later the trees of sufficient size have been cut down and sold to be sawed into cabinet lumber. The tree is becoming quite common, however, in cultivation, for which purpose it is very valuable, not only for its timber and shade, but for its fine shape which makes it well adapted for planting along roads and driveways. The delicious nuts which it yields abundantly are great favorites with the young people. It is most successfully raised from the seed planted where the trees are to remain, as its deep taproot makes its transplanting difficult.

3. *Hicoria minima* (Marsh), Britton. (*Carya amara* Nutt). Bitternut. Our only hickory; a small tree with very hard, close-grained wood, useful for many purposes, such as handles for tools. The thick-shelled nuts are of little value. The tree has a wide distribution in this region, but is nowhere very plentiful.

SALICACEÆ.

4. *Populus alba* L. White or Maple-leaved Poplar. This European tree is very frequently planted for shade, but is not to be recommended, as it spreads very badly by its roots. It has escaped from cultivation in many places.

5. *Populus tremuloides* Michx. Poplar. Trembling Aspen. A graceful little tree, quite frequent in woods, and one which formerly was occasionally found in clumps on the prairie. As it spreads by its roots, like its European cousin, and will grow

up again if burned over, it was better fitted than most of our native trees to survive the prairie fires; a great enemy of our native forest development. Its beautifully shaped leaves are so hung on the slender, flattened petioles, so as to rustle in the slightest breeze. With us the tree does not reach a size to make its soft wood of much value except for fuel.

6. *Populus deltoides* Marsh. (*Populus monilifera* Ait.). Cottonwood. This large tree, everywhere common in cultivation, was very rare in this county in early days. Mr. M. Richmond, who settled in Armstrong Grove township in 1868, reports one large tree, then a foot in diameter, south of the East Fork of the Des Moines river, not far from his home, and also a few smaller ones elsewhere along the river. The larger one must have been a native before the coming of the white settlers, as its size would indicate, the first settlement having been made in that section about 1865.

Regarding this species the Hon. Howard Graves, of Estherville, who came to the county only four years after the first settler, writes the author as follows: "When I came to this county, A. D. 1860, there was one large cottonwood tree (evidently native) growing on the west bank of Ryan lake. In this tree eagles nested for many years. The water finally washed around the roots of the old cottonwood, and it toppled over into the lake where it now lies in a state of decay. There were at the time mentioned a few other native trees of the cottonwood species on the south bank of Turtle lake; none on the West Fork of the Des Moines river or in the immediate vicinity of Estherville."

The early settlers planted this species extensively as a shade tree around their dwellings and along roadsides, its very rapid growth making a quick return for the labor used in planting and cultivating. Trees thirty-five years old frequently measure two feet in diameter and seventy feet in height. The wood is soft and perishable, but when seasoned is quite valuable for fuel. The tree does not thrive on the prairie when planted in a grove, only the outside row or two doing fairly well; but when given plenty of room, the rapidity of its growth is all that could be desired. Though once so rare, it is escaping

from cultivation in many places. This tree, like all the willows and poplars, is diœcious, the stamens and pistils being borne on separate trees, and its small seeds, each with its tuft of cotton, is a source of great annoyance to tidy housewives. If cuttings for planting were taken only from the staminate or sterile trees this objectionable feature would be removed.

7. *Salix nigra* Marsh. Black Willow. Frequent along streams and lake-shores. It sometimes attains a very large size, forty to fifty feet in height, with a trunk a foot in diameter. This and the following species usually bend gracefully over the water, their leaves and slender branches reaching down as if to kiss the face of the stream that smiles in the sunshine below. The wood though soft is quite durable and is valuable for fuel and fence posts, for which purposes it was much used by the early settlers.

8. *Salix amygdaloides* Anders. This large tree is similar to the preceding, and grows with it. It may be recognized by its broader leaves, about one inch broad and three to five inches long. It seems to be widely distributed throughout this region.

9. *Salix alba vitellina* (L.) Koch. White Willow. This is the form in universal cultivation throughout this part of the west, and is very valuable for forming a hedge or windbreak where a quick return is especially desirable. When planted in single rows the growth is used for summer wood and for fence posts. For this latter purpose the posts should be four to six inches in diameter, and if well seasoned will last from three to ten years.

A large clump planted on some low corner in the permanent pasture will afford a fine shade, and will be greatly appreciated by our dumb friends on hot summer days. While not a native of this country, this willow has escaped from cultivation and is frequently found along highways and streams.

10. *Salix fluviatilis* Nutt. (*S. longifolia* Muhl.) Sand-bar Willow. This is a much branched shrub, seldom attaining the size of a small tree, which grows in clumps along streams and in marshes. It is of little value, though sometimes used for fuel when nothing better is at hand. This is our most common species.

11. *Salix bebbiana* Sargent. (*S. rostrata* Richards.) Bebb's Willow. Occurring as a shrub in a large marsh, two miles north of Armstrong.

12. *Salix humilis* Marsh. Prairie Willow. This little shrub is very rare in this region. It is seldom more than two or three feet high, and occurs on prairies or borders of woods.

13. *Salix discolor* Muhl. Glaucous Willow. A shrub or small tree which attains a height of ten to twenty feet in this locality. It occurs along streams, but more frequently in marshes or on low prairies. Its leaves when mature, are a bright glossy green above and whitish underneath, hung gracefully on the slender branches, make this a beautiful species.

14. *Salix sericea* Marsh. Silky Willow. A most beautiful shrub. The young leaves are silky-pubescent, but later in the season are a dark, glossy green. Rare in marshes near Armstrong.

15. *Salix cordata* Muhl. Heart-leaved or Pussy Willow. A straggling shrub five to twelve feet high, very common in clumps along streams and on low prairies. Of no economic value. The closely allied *S. missouriensis* Bebb, occurs at Okoboji, Dickinson county.

16. *Salix myrtilloides* L. Bog Willow. This is a beautiful little shrub about two feet high. A large patch of it occurs in a marsh three miles north of Armstrong, the only locality known in the state. It ranges from New Jersey to Iowa and northward into British America, and is also common in northern Europe, being the only Iowa willow native to both the Old and the New World.

BETULACEÆ.

17. *Ostrya virginiana* Walt. Hop Hornbeam. Ironwood. This small tree is easily recognized by its hop-like fruit. Its very hard wood is useful for various purposes, like the hickory. Though very common in woods with us, it never attains much size.

18. *Corylus americana* Walt. Hazelnut. This low shrub is much less common in this region than in the eastern and southern parts of the state. It is found rather sparingly on the

borders of woods or along river bluffs. Its fruit, ripe in August or September, is eagerly sought by the children, as well as by their friends, the squirrels and chipmunks.

FAGACEÆ.

19. *Quercus rubra* L. Red Oak. This oak, which becomes a large forest tree in more favored localities, seldom attains any considerable size in this region. It is frequent in the woods near Estherville. Though a very pretty tree, it does not possess much value except as fuel.

20. *Quercus macrocarpa* Michx. Bur Oak. This is our hardiest tree as well as our commonest hard-wood species. It varies from a large tree in favored localities, to a gnarled and straggling shrub on the river bluffs and the outskirts of the woods. Single trees are occasionally found at long distances from any other timber where they have, sentinal-like, withstood the buffetting storms for centuries.

Like all the oaks it cannot be transplanted successfully, unless at great expense, and for this reason, as well as because of its slow growth, it is not used in cultivation. The wood is hard, strong and close-grained and is very valuable for fence posts and fuel. The white oak does not occur in this county, its nearest station being at Algona twenty miles southeast of our limits.

ULMACEÆ

21. *Ulmus americana* L. White or Water Elm. This large tree is very common along large streams, and is our most valuable native species for a shade tree along streets and around dwellings. It is perfectly hardy, and its tough, wiry branches withstand the wind remarkably well. Its wood, quite valuable for fuel, is difficult to split.

22. *Ulmus fulva* Michx. Slippery Elm, Red Elm. A smaller tree than the preceding, and comparatively rare in this region. The wood is stronger and more durable than that of the white elm. The mucilaginous inner bark is often chewed by children, and is used to some extent in medicine.

Ulmus alata Michx. The Winged Elm has been found in Dickinson county by Prof. T. H. Macbride.

23. *Celtis occidentalis* L. Hackberry. This large tree attains only a medium size with us. It occurs scattered through woods and along river banks, and shores of lakes. The tree has the aspect of the elm. Its small, berry-like fruit, ripe in August, is said to be sweet and edible. The wood is weak and coarse grained.

SAXIFRAGACEÆ.

24. *Ribes cynosbati* L. Gooseberry. This species occurs in the woods west of Estherville, but is much less common than the next. Its fruit is quite large and covered with prickles.

25. *Ribes gracilis* Michx. Gooseberry. This smooth-fruited shrub is very common and is sometimes transplanted to gardens. The fruit, which when ripe is very pleasantly flavored, is occasionally offered for sale in the market.

26. *Ribes floridum* L'Her. Wild Black Currant. This is a very common shrub in low woods and along the banks of streams. The fruit has a flavor similar to the black currant of the gardens, and is liked by some persons. The bush is handsome when in bloom, and should be used for ornamental purposes.

ROSACEÆ.

27. *Spiraea salicifolia* L. Meadow-sweet. This beautiful little shrub, two to four feet high, is very common on low prairies and along streams. Its graceful panicle of white or rose-tinted flowers makes a pretty sight. It is scarcely inferior to some of the cultivated species.

28. *Rubus strigosus* Michx. Wild Red Raspberry. Frequent in woods. The light red fruit is very pleasant to the taste. This species is the original of the Cuthbert raspberry of cultivation.

29. *Rubus occidentalis* L. Wild Black Raspberry. A common species in woods, the original of the "black cap." The artificial groves contain many of these black raspberries which

have grown from seeds dropped by the birds, and it is impossible to distinguish between those derived from the wild and the cultivated stock.

30. *Rubus villosus* Ait. ' Blackberry. A few plants of this species were found twenty-two years ago in the woods west of Estherville, but they have probably disappeared before this. These three species of bramble are not true shrubs, the stems being biennial.

31. *Rosa blanda* Ait. Wild Rose. This pretty shrub, two to four feet high, is restricted to the woods and river banks. Its stems are only sparingly armed with prickles, the leaflets are usually three to five in number. Those who love our wild flowers as nature left them, will find this a desirable shrub for cultivation.

32. *Rosa arkansana* Porter. Prairie Rose. The small wild rose, so common everywhere on our prairies, is this species. The stems densely covered with prickles are far from pleasant to handle when bound in a bundle of grain. The roots are so deep seated that only very deep plowing and the most thorough cultivation will destroy them. It, however, does little harm in our fields, and one can readily forgive a few scratches for the pleasure of seeing its beautiful flowers at his feet as he labors, showing every shade of color from pure white to the deepest red and crimson.

POMACEÆ.

33. *Malus ioensis* (Wood) Britton. (*Pyrus ioensis* Bailey). Wild Crab Apple. This small tree, now considered distinct from the form occurring in the eastern states, is found but rarely in this region. When in full bloom one could scarcely wish a prettier sight, and for this reason, as well as for its bright foliage, it is a desirable ornamental tree, although it is somewhat difficult to transplant from the woods. The fruit is pleasantly scented, and very acid.

34. *Amelanchier alnifolia* Nutt. Serviceberry. This pretty shrub, four to eight feet tall, is found on bluffs along lakes, and in high woods. The fruit, ripe in June, is very pleasantly flavored, and seems to be liked equally well by birds and people.

35. *Cratægus punctata* Jacq. Hawthorn. This small tree is quite common in the woods around Iowa lake. The large red fruit is not unpleasant to the taste.

36. *Cratægus coccinea* L. Scarlet Thorn. This is our most common hawthorn, or thorn apple. This beautiful small tree or shrub is found in thickets, and occasionally in artificial groves where it has evidently been introduced by birds. It is also sometimes seen in cultivation for which purpose it is well suited.

37. *Cratægus mollis* (T. & G.) Scheele (*C. subvillosa* Schrad). Hawthorn. Thorn Apple. Woods, rather rare. The broad leaves are very soft to the touch, especially when young. The large red fruit is not unpleasant to the taste. This is also a desirable tree in cultivation. In later years so many new species have been segregated from the few formerly recognized that the three given here may include several of the new species, but in the present unsettled condition of the genus it seems best to await further developments before attempting to prolong this list.

DRUPACEÆ.

38. *Prunus americana* Marsh. Wild Plum. This is a shrub or small tree with a profusion of small thorns. Though often cultivated, it does not bear much fruit after a few years. The large yellow or red fruit is very much desired for canning and jelly, and formed an important addition to the few luxuries of the early settlers before the introduction of other fruits. The tree is very common throughout the state, preferring the margins of the woods or the dry banks of lakes and streams.

39. *Prunus virginiana* L. Choke Cherry. This is a shrub six to eight feet high, growing in clumps in open woods, or on bluffs along streams and lakes. It is troublesome in cultivation as it spreads very readily by the roots. The fruit is nearly black and very astringent.

40. *Prunus serotina* Ehrh. Wild Red Cherry. This tree which attains a very large size in the eastern states, occurs sparingly in the woods west of Estherville, where it is quite small, attaining a height of ten to twenty feet. The strong

reddish-brown wood of this species is very valuable in cabinet making. The fruit, which is a dark red, and only slightly astringent, is occasionally used for food.

PAPILIONACEÆ.

41. *Amorpha fruticosa* L. False Indigo. A shrub six to eight feet tall, common in open woods and along streams.

42. *Amorpha nana* Nutt. (*A. microphylla* Pursh.) False Indigo. A very beautiful little shrub growing in clumps and common on the prairies of northwestern Iowa. In its small leaves, their color and surface, and the general appearance of the shrub, it bears a close resemblance to the box. The numerous spikes of flowers appear in May or June and are very showy. The plant would seem to be worthy of cultivation.

43. *Amorpha canescens* Pursh. Lead Plant. Shoe-String. This is a shrubby plant about two feet high, with spikes of bright, indigo-blue flowers, which are very pleasantly scented. The strong roots offer considerable resistance to the breaking plow, whence the popular name shoe-string. It grows very commonly on rather dry prairies and borders of woods.

44. *Robinia pseudacacea* L. Locust Tree. This ornamental tree from the Atlantic states is frequent in cultivation, and has escaped in a few places. Its wood is said to be very durable for posts.

RUTACEÆ.

45. *Xanthoxylum americanum* Mill. Prickly Ash. This pretty shrub or small tree is quite common in thickets and occasionally introduced by birds into artificial groves. Its pinnate leaves and mature capsules, displaying the shining black seeds are very pretty, but the numerous prickles on twigs and petioles are a serious objection.

ANACARDIACEÆ.

46. *Rhus hirta* (L.) Sudw. (*R. typhina* L.) Staghorn Sumac. This is our rarest and handsomest species. Only a few shrubs have been found on the river bluffs southwest of Armstrong, and near Iowa lake. The graceful, fern-like leaves, as well as

the bright crimson foliage and fruit in autumn, make it a desirable plant for cultivation. Its only drawback is its liability to spread by the roots.

47. *Rhus glabra* L. Smooth Sumac. Common everywhere near woods and on the bluffs along lakes and rivers. It is almost as pretty a shrub as the preceding. The showy fruit, ripe in autumn, is covered with short, red, acid hairs.

48. *Rhus radicans* L. Poison Ivy. In this locality this plant only occurs as a low shrub, one to two feet high. The leaflets are in threes, and the clusters of dry, whitish berries are carried on the plant all winter. It is very poisonous to most people, and for this reason should be destroyed, especially if found around dwellings. It should not be confounded with the beautiful virginia creeper, which is also very common. The latter always has the leaflets in fives. The climbing form of the poison ivy probably does not occur in this part of the state.

CELASTRACEÆ.

49. *Euonymus atropurpureus* L. Wahoo. Burning Bush. A shrub or small tree, very rare here, having been found only in the woods near Estherville. When the capsules open in autumn, displaying the dark colored seeds in their red setting, the plant is highly ornamental.

50. *Celastrus scandens* L. Climbing Bittersweet. This beautiful woody vine climbs trees to the height of ten to twenty feet. When the seeds are displayed in autumn in their scarlet arils, they are very attractive, and are much used for house decoration in winter. The vine is more commonly found in thickets and is also occasionally seen in artificial groves where it has probably been introduced by birds. Both this and the preceding species are frequently cultivated.

STAPHYLEACEÆ.

51. *Staphylea trifolia* L. Bladder Nut. A shrub about four to eight feet high with pretty, trifoliate leaves, and seeds enclosed in bladder-like capsules. It was found only in one place in the woods west of Estherville, and is probably very rare in this region.

ACERACEÆ.

52. *Acer saccharinum* L. (*A. dasycarpum* Ehrh). Soft Maple. This tree is native along both the East and West Forks of the Des Moines river, but is much more common in cultivation. It is one of our most useful and rapidly growing shade trees, and worthy of much more attention than it receives. Planted in a hedge for a windbreak it does very good service, growing when planted closely, tall and slender, like the white willow. Planted along the road, or on the lawn, it will assume very fine proportions if properly pruned. When given plenty of room it is a very rapid grower, and its branches are somewhat easily broken by the wind, but, if after the trees have attained a height of ten to twelve feet, a heavy blue-grass sod is allowed to form around them the growth will be sufficiently retarded to render the wood much tougher, and less liable to injury. The tree is remarkably free from insect enemies. The wood is quite valuable for fuel, but is of little value for posts, as it decays rapidly when placed in contact with the soil. The trees are best raised from seed, planted a few inches apart in rows which are at a sufficient distance from each other to allow of thorough cultivation. Young trees are easily transplanted to their permanent location when five or six feet high, which will be in about three years.

53. *Acer nigrum* Michx. Black Sugar Maple. Common on high ground in woods near Iowa lake and Estherville. It is a most beautiful tree, and is valuable for its strong, close-grained wood. As a shade tree for lawns and parks it is very much admired, but seems prone to die in the top when transplanted to our heavy prairie soil. The trees in this region are mostly small in size and have been used very little for the purpose of making maple sugar.

54. *Acer negundo* L. (*Negundo aceroides* Moench.) Box Elder. A small tree, very common along streams, which is destined, now that the days of prairie fires are ended, to play an important part in lining their banks with timber. The tree is not a desirable one for planting on the lawn or along the street because of its low branches and bushy appearance, as well as its liability to be infested by a species of bug marked with red,

known as the Indian bug, which often gather on it in great numbers and enter houses to the great annoyance of tidy housewives. Its wood is of some value for fuel.

RHAMNACEÆ.

55. *Ceanothus americanus* L. New Jersey Tea. Red Root. This beautiful little shrub, one to two feet high, grows in dry soil on prairie hillsides, and on the border of woods. It is easily destroyed by pasturage or cultivation, and is rapidly disappearing.

VITACEÆ.

56. *Vitis vulpina* L. (*V. riparia* Michx.) Wild Grape. This shrubby vine is very common in low woods, especially along streams. The acid fruit, ripe in September, is largely gathered for making wine and jelly. It is becoming very plentiful in the artificial groves where its seeds have been left by the birds. It is extremely hardy and stands the cold of our severest winters without injury.

57. *Parthenocissus quinquefolia* (L.) Planch. (*Ampelopsis quinquefolia* Michx.) Virginian Creeper. This beautiful climbing vine is perfectly hardy and is worthy of extensive cultivation. Its leaflets are in fives which at once distinguishes it from those of the poison ivy which are in threes. The black berries and crimson leaves in autumn add still more to its atttractiveness. By the means of adhering disks at the end of its tendrils, it readily climbs the side of a building without other support. Common everywhere in woods, it is rapidly being introduced into artificial groves by the birds.

TILIACEÆ.

58. *Tilia americana* L. Basswood, American Linden. This handsome tree, native along streams, prefers soil not too low, but where its roots can secure an abundance of moisture. The sweet-scented flowers are great favorites with the bees. It is a desirable tree for the lawn wherever some shelter from heavy winds is afforded. Its soft wood is quite valuable for fuel, and in early days many of the larger trees were sawed into lumber.

CORNACEÆ.

59. *Cornus circinata* L'Her. Round-leaved Dogwood. This pretty shrub, four to ten feet high, grows in clumps on river banks, but is not common. Its broad, thin leaves at once distinguish it from our other species of the genus.

60. *Cornus asperifolia* Michx. Rough-leaved Dogwood. This small shrub occurs in woods near Iowa lake, and Armstrong Grove and is probably frequent in this portion of the state.

61. *Cornus stolonifera* Michx. Dogwood. This pretty little shrub with reddish purple twigs grows in dense clumps along streams. It is not so common as the next species.

62. *Cornus candidissima* Marsh. (*C. paniculata* L'Her.) Dogwood. Our commonest species, everywhere along lake shores and water courses where other timber is found. This shrub has white fruit.

63. *Cornus alternifolia* L. Alternate-leaved dogwood. This is our largest species of the genus, being a tall shrub, or small tree. It occurs sparingly along the south bank of the Des Moines near Armstrong, and in the woods west of Estherville.

OLEACEÆ.

64. *Fraxinus lanceolata* Borck. (*F. viridis* Michx.) Green Ash. This is one of our most valuable native trees; everywhere common along the larger streams and lake shores. Its rapid growth and strong, durable wood make it a valuable tree for planting in grove or lawn. It was very largely used for fuel by the early settlers, as well as for supports for the hay sheds which were the barns of the pioneers. It bears transplanting to the prairie soil remarkably well and is reasonably free from injury by wind-storms and insect enemies. The white ash, a larger and more valuable species, has not been found within our limits.

CAPRIFOLIACEÆ.

65. *Sambucus canadensis* L. Black Elderberry. This pretty shrub, so common in the Eastern states, is occasionally found in our woods where it is undoubtedly native. It is often trans-

planted to gardens for the sake of its graceful shape, and its berries, which are used for pies. The red-berried elder (*S. pubens* Michx.) occurs twelve miles north of our county line, in southern Minnesota.

66. *Viburnum pubescens* (Ait.) Pursh. Arrowwood. This is a low, branching shrub, with nearly black berries. It occurs in the woods west of Estherville.

67. *Viburnum lentago* L. Nanny Berry, Sheep Berry, Black Haw. This pretty shrub is frequent in woods, preferring high banks near water. Its flowers are very attractive in May; its fruit, ripe in October, is edible and much liked for its peculiar shape, and pleasing flavor. It is a near relative of the snow ball of the gardens.

68. *Symphoricarpus occidentalis* Hook. Wolf-berry. A neat little shrub, very common in open woods, and occasionally on gopher knolls on the prairie. The clusters of pretty, whitish flowers are succeeded in August by the white berries which remain long after the leaves have fallen.

69. *Lonicera dioica* L. (*L. glauca* Hill.) Honeysuckle. The only true honeysuckle found in this county. It occurs in open woods, and is worthy of cultivation. If planted alone it is self-supporting, but it usually twines around shrubs or other supports when they are within reach. The plant in the woods commonly called honeysuckle by the children, is a species of columbine (*Aquilegia canadensis* L.)

It thus appears that there is hardly a woody plant in northwestern Iowa but that is worthy not simply of preservation, but of cultivation as well, at the hands of the intelligent farmer. It is hoped that even the preceding list may serve to awaken renewed interest in this part of the natural resources of our country, and that, in consequence, each succeeding year may see increasing numbers of our people surrounding their homesteads with native trees and shrubs, alike to their own enjoyment and comfort and to the advancement of our common prairie home.

GEOLOGY OF JASPER COUNTY.

BY

IRA A. WILLIAMS.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Jasper county is in the fourth tier of counties from the southern and in the sixth from the northern border of the state occupying a central position from the east and west. It is larger than the ordinary interior Iowa county and is bounded by six surrounding counties. Story and Marshall lie to the north, Poweshiek to the east; Maskaska and Marion bound it on the south; and Polk county is the western boundary. It includes twenty congressional townships, in tiers of five townships east and west and four north and south. The lower tier has an offset to the east of approximately one-half mile by a correction line, and is divided into four civil townships whose boundaries are somewhat irregular on account of the diagonal course of Skunk river. The three eastern members, viz., Washington, Mound Prairie and Palo Alto, of the second tier from the south, likewise vary in size from the standard of thirty-six sections. The county, therefore, embraces an area of seven hundred and twenty square miles and contains a little less than one-half million acres.

HISTORY AND PREVIOUS GEOLOGICAL WORK.

The name Jasper was given to the area under consideration, and its present boundaries established, in 1846, some months before the admission of Iowa as a state. It was named after Sergeant Jasper of Revolutionary fame,* and was included in the "New Purchase" ceded to the government by the Sacs and Foxes in 1842. By the terms of this treaty, white men were allowed to enter the acquired territory in May, 1843, and in this year the first settlement was made at the present location of the town of Monroe. The present county seat was located early in 1846 and surveys of the county were completed in 1847.† No record is found of geological observations in the county previous to the work of the official survey by James Hall, pub-

* McGee: Pleistocene History of Northeastern Iowa, 11th Ann. Rep. U. S. G. S., p. 208.

† These historical facts were gleaned largely from "History of Jasper County" by Western Historical Co., Chicago, 1878.

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PHYSIOGRAPHY.

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*General Features.**—The surface configuration of Jasper county is to be attributed almost wholly to the glacial drift. The topographic features are those resulting from the action of weathering and erosive agents on this superficial deposit. the drift materials respond comparatively readily to the cutting of streams, so that, although these deposits are geologically not old, the county in general is well drained and the land forms are those moulded largely by water action. This statement holds good for the major portion of the county but would scarcely be applicable in its strictest sense to the small area of Wisconsin drift in the northwest corner. In this area, covering parts of Clear Creek, Poweshiek and Washington townships, drainage is imperfect and the land surface still retains the characteristic imprint of the ice moulding of the last great glacier.

The remainder of the county is covered by the Kansan drift which is responsible for the general outlines of the surface features. It is true that the Kansan is entirely overlain by the loess, but this last deposit has conformed with such fidelity to the contours of the pre-existing surface that the drift is to be considered the determining factor. Exceptions to this are occasionally met, as in the case of the sand hills along the Skunk river; and a few points along this river where the outcropping Coal Measures give character to the topography.

We may therefore separate the county into two parts based on the character and age of its topographic features. The Kansan drift area, a mature topography; and the Wisconsin drift, a region of comparative youth.

* The surface features of Jasper county are treated in a general way in Pleistocene History of Northeastern Iowa, 11 Ann. Rep. U. S. G. S., pp. 223-225.

lished in 1858*. In this report mention is made of exposures of Carboniferous rocks on Rock creek and North and South Skunk rivers, and of the fact that the Coal Measures underlie essentially the whole of Jasper county. Brief descriptions of the coal mines west of Newton are also included, the Slaughter coal bank near the present town of Colfax having then been worked for several years.

The final report† of the next authorized geological survey of the state, that by Charles A. White, published in 1870, contains a reference to the coal mines west and south of Newton, and the prediction was made that large supplies of coal could be relied upon for the future.

The State Mine Inspectors' reports from 1880 to the present time contain much information concerning the coal mining industry of the county.

McGee‡, in "Pleistocene History of Northeastern Iowa" describes the surface features and character of the superficial drift deposits of this area. Brief mention is also made of the irregular bedding and arenaceous character of the Carboniferous strata.

Since the organization of the present survey, geological work has been carried on in Marshall and Story counties to the north, Polk to the west and in Marion county to the south. The results of these investigations have been published in the Annual volumes of the Geological Survey.§

Much information regarding the Coal Measures and the coal mining industry is contained in Dr. Keyes' report on the "Coals of Iowa".‖ Data on the deep wells, and especially the mineral water wells at Colfax, are included in Professor Norton's report on the "Artesian Waters of Iowa".¶ A report on the clay interests of the county is embraced in Volume XIV of the Annual Reports of the Iowa Geological Survey.**

* Geol. Surv. State of Iowa, Vol. I. pt. 1, pp. 266 and 272, 1858.
† Geol. Surv. State of Iowa. Vol. II, p. 262, 1870.
‡ 11th Ann. Rep. U. S. G. S., pp. 228, 311, 508.
§ Geology of Marshall County, S. W. Beyer, Iowa Geol. Surv., Vol. VII, p. 199.
Geology of Story County, S. W. Beyer, Iowa Geol. Surv., Vol. IX, p. 155.
Geology of Polk County, H. F. Bain, Iowa Geol. Surv., Vol. VII, p. 265.
Geology of Marion County, B. L. Miller, Iowa Geol. Surv., Vol. XI, p. 127.
‖ Coals of Iowa, Ann. Rep. Iowa Geol. Surv., Vol. II, pp. 294-506.
¶ Artesian Wells of Iowa, Iowa Geol. Surv., Vol. VI, pp. 298-381.
** Clays of Iowa, Iowa Geol. Surv., Vol. XIV.

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Kansan drift area.—The characteristics of the Kansan drift topography do not differ here from Marshall county to the north and Marion to the south, which have been described by Beyer and Miller respectively. So universally is this drift covered with the loess that the contours are today largely expressed in this pebbleless, silty material. It might thus be appropriately designated loess-Kansan topography, since the relief of the county is due to erosion in the drift itself, while the conspicuous features are generally attributable to the mantle of loess.

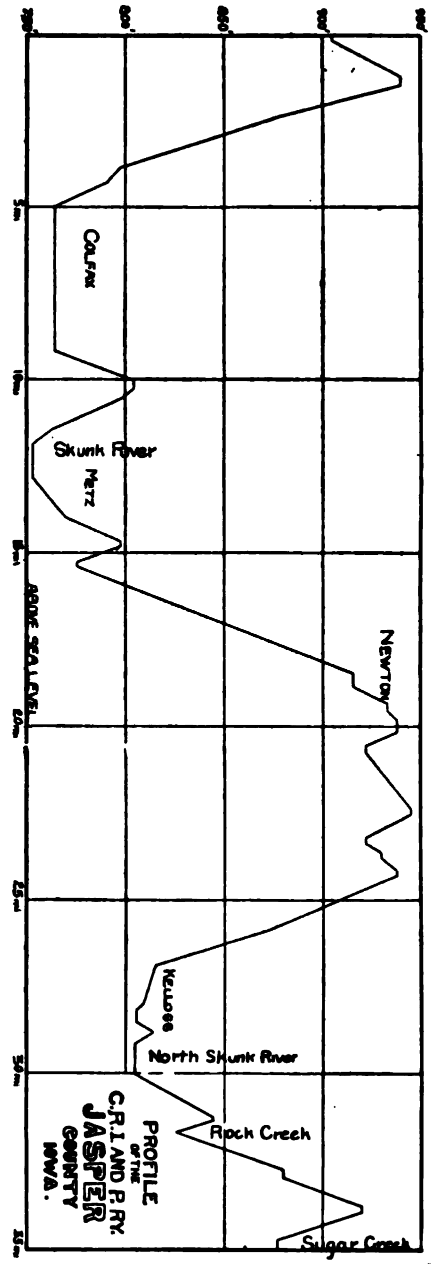

Fig. 19. Profile of the Chicago, Rock Island and Pacific railroad across Jasper county.

Essentially nine-tenths of the county is included in the loess-Kansan area. In this territory the extreme range between points whose elevation is accurately known is 310 feet. The level divide on which Newberg, and to the north, Gilman, in Marshall county, are located, has an altitude of 1,060 feet above the sea. The elevation of Prairie City, which is likewise built on a flat divide separating the Skunk and Des Moines river systems, is 920 feet. Lynnville has an elevation of 938 feet. The town of Collins, some three miles over the line in Story county, is 997 feet above tide, while Monroe, near the

south edge of Fairview township, Jasper county, has an altitude of 909 feet. Skunk river, at the Chicago, Rock Island & Pacific crossing is 753 feet, which is the lowest recorded point. The general slope of the area is therefore to the south, and the trend of the major streams is towards the southeast.

The relief ranges from a few feet on the level divides, which are not deeply dissected by the streams, to 150 feet or more between valley floor and adjacent hilltops in the more dissected areas. Such strong relief is conspicuous in Rock Creek township where Rock creek and its branches have cut deeply into the drift. Cherry creek in Newton township, and Clear and Mud creeks in Independence and Clear Creek townships have also deepened their valleys to such an extent in keeping pace with the parent streams that the topography in these parts is decidedly rugged. Along the south border of the county in Fairview and Des Moines townships the features are abrupt, but the relief is not so great.

Viewed broadly, it appears that the surface of the Kansan drift after the retreat of the glacier was a fairly level plain. The irregularities found today are those only that would result from the work of the streams in developing a drainage system, and from the deposition of the superficial covering of loess. The divides which separate the headwaters of the members of the several drainage systems represented are conspicuously flat and are remnants of the original drift plain. Many of the hills along the larger streams, and especially on the western borders of their valleys, are flat topped and the general aspect of the sky line is that of an interrupted straight line. This is especially noticeable along the North Skunk river in Richland township, and may be observed at many other points along this and other streams in the county.

The general levelness of the drift surface has been in places modified by the loess which covers it. In some cases its influence has been to moderate and subdue the ruggedness of the strictly erosional surface. In others, the relief has been exaggerated. But over the whole of the Kansan drift area, as has been noted, the chief topographic forms existing before the loess was deposited are not obscured, but rather preserved. It is to

be observed that the loess is present as a continuous mantle over the level divides as well as a capping to the most prominent hills, and a veneer extending low down the hillsides into the stream valleys. The original abruptness is thus somewhat mellowed and a characteristic type of land surface developed. The forms have a rounded and pleasing fullness of contour that is not readily mistaken.

In the more hilly parts of this area the bowldery clay of the Kansan is frequently found outcropping on the middle slopes of the hills. Its angle is usually different from that maintained by the loess, thus causing a break in the general symmetrical outline of the hill. At a few points in the narrow belt of Red Rock sandstone, which extends from northeast to southwest nearly across the county, the underlying ledges of this rock give a characteristic stamp to the surface features. This is especially noticeable along the north border of the North Skunk valley just east of Kellogg, and the west boundary of Skunk river west of Reasnor southward into Fairview township. In the mining districts where the coal-bearing strata frequently outcrop along small streams and in road cuts, and where the drift is thin, the argillaceous sandstones and sandy shales are often responsible for the principal elevations. South of Newton, in Palo Alto township, and eastward from Monroe in Fairview and Elk Creek townships are areas notable in this particular.

At various points along both the east and the west banks of Skunk river valley are found prominent sand hills and ridges. These are distributed from the Wisconsin drift area in Poweshiek township to the exit of the river from the county in Elk Creek township, but are more numerous to the east than to the west of this stream. They range from low, flattened ridges of dune-like character that stretch out into the valley itself, to the more prominent elevations that form the valley walls. The sand hills are universally capped with loess sometimes thin, but often in sufficient amount to impart to the topography the characteristics of the loess bluffs as developed along the Missouri river. In places the sand seems to grade upwards into the loess. The importance of these feat-

ures is great. In the northeast ¼ of section 33, Elk Creek township are small areas of shifting sands. The roads are everywhere sandy and in places little can be accomplished towards tillage of the land. Again in the south part of section 13 of the same township, south of Reasnor, where sand has been removed, are observed fields which the shifting sands are gradually rendering valueless. Just south of Colfax, back of the loess bluffs on which a portion of the town is built, are areas of very sandy loess which works up in the country roads and makes traveling anything but agreeable. The origin of these sand deposits will be spoken of under Geological Formations.

FIG. 20. Moving sands in the valley of Skunk river, southeast quarter of section 13, Elk Creek township.

A discussion of the topography would be incomplete without referring to the river valleys and their flood plains. They appear to be features of post-glacial development largely. All of the principal streams are skirted by alluvial flood plains of greater or less width and, although subject to occasional inundation during high water, afford some of the most fertile farming land in the county.

Iowan drift plain.—The border of the Iowan drift as located by Dr. Beyer * in Marshall county lies north of the Iowa river, and only the northeast corner of that county is covered by the till of this age. Prof. T. E. Savage † has shown that a considerable area in the southern part of Tama county is to be included in the Iowan drift plain and that it probably extends into southern Marshall and southward into Poweshiek county. The plain mapped as Iowan in southwestern Tama county is coextensive with the flat divide on which Gilman in Marshall county and Newberg in Jasper county are situated. Topographically this region appears to possess the characteristic Iowan surface. Wherever exposures can be examined, however, it is found to be covered with loess, and in this particular as well as in the monotonous level of its surface, is not different from similar stream divides in other parts of Jasper county. To the south and west where the plain gives way to the erosional type of topography, and wherever, in the plain itself, sections are available, thé material beneath the loess is typical Kansan drift.

Aside from the criterion of topography, the presence of unweathered granite bowlders is regarded as confirmatory of the Iowan age of this drift plain in Tama county. The large, fresh, pink and grey granites are especially characteristic of this drift, and where typically developed are an ever present feature. In Jasper county bowlders are seldom seen except along some of the minor stream cuts where the drift underlying the loess outcrops on the lower slopes. In these instances the prevailing type is the red granite, and from position alone is presumably genetically related to undoubted Kansan drift. In fact, at no point in the county was there observed a drift section which presented the characteristic facies of the Iowan. It is true that over the section included in Hickory Grove and Mariposa townships more outcropping bowlders can be counted than over any other of equal area in the county; yet only in a single instance was there seen one of such unusual size and freshness as to suggest an origin other than the Kansan

*Iowa Geol. Surv., Vol. VII.
†Iowa Geol. Surv., Vol. XIII.

drift, with which it appeared to be associated. Near the northwest corner of section 29, Hickory Grove township, is a coarse-grained, red granite, whose dimensions are approximately thirty feet long by twelve feet high by eleven feet through above ground. It is so situated on the slope near a sharp gully that the larger portion of the rock may yet be below the surface. Undoubted Kansan drift is exposed in the road fifteen to eighteen feet above the bowlder. In species, dimensions and freshness it is very unlike those characteristic of the Kansan, and it seems safe to relate it in origin with the

FIG. 21. Granite bowlder in the northwest quarter of section 29, Hickory Grove township. Dimensions approximately 30x11x12 feet.

Iowan drift sheet. In section 24, Kellogg township, a moderately large, red granite was observed, but this showed the effects of weathering to such a degree that but little could be concluded as to its age.

The facts at hand are not sufficiently definite to permit of the location of a positive border to the Iowan in Jasper county. The surface features are not such as require the presence of this drift to account for them, for, as has been shown, areas similar in every way are to be found in other parts of the county where Iowan drift would be out of the question. Sections through the loess do not bring to light at any point drift materials referable to the Iowan. The bowlders, some of which are in species and condition unlike those predominating in the Kansan drift, afford the strongest evidence of the possible extension of the Iowan ice over this region. It should also be observed that the pink and grey granites are the typical bowlders of the Iowan, although red granites are known to occur. All those observed in Jasper county are of the red or pink variety. The presence of the bowlders is perhaps best explained by attributing them to the Iowan glacier. If the ice once stood over this area it was in all probability very thin and the material carried small in amount. Being near the extreme limit of ice movement, wasting may have progressed so far that little erosive power remained and the transported rock detritus was insufficient to exert an appreciable influence on the nature of the pre-Iowan land surface.

Wisconsin drift area.—The portion of the county whose topography depends upon this new sheet of drift is comparatively small. The features which it exhibits are as a rule not especially pronounced, in which respect this area differs from the characteristic development of the Altamont moraine in the north-central and northern parts of the state. Although the border of the Wisconsin ice rested here during the period of maximum southern extension in the state, morainal features are found at but one point. This is in the south part of Clear Creek township, sections 27 and 28, 33 and 24, where a series of kame-like knolls and elongated ridges have displaced Indian creek from its earlier course. The thickness of the ice and the amount of material carried appear not to have been large.

The immature nature of this area is evidenced by the presence of marshy areas with occasional ponds, although these characters are far less common than they are further within

the Wisconsin drift plain. The change most noticeable in passing from the Kansan drift to the Wisconsin drift is the relative mildness of the topography of the latter. The loess covered Kansan is deeply incised and the relief is considerable, while over the Wisconsin drift these erosional features have been largely obliterated by filling and leveling, thus leaving a more level surface. This is especially noticeable in Clear Creek township near the north county line. At the edge of the Wisconsin area, the river valleys are narrow as a rule, and in some instances a partial filling of old depressions by the newer drift is evident. The filling has seldom been sufficient to obscure former valleys or to displace the streams. The border line between the two drifts is frequently marked by low, boggy slopes where springs are not uncommon.

The following table of elevations of various points over the county has been compiled principally from profile data of the different railroads.

LOCALITY.	ALTITUDE ABOVE SEA.	AUTHORITY.
Railroad bridge, North Skunk river	941	C. & G. W. Ry.
Baxter	1033	C. & G. W. Ry.
Ira	862	C. & G. W. Ry.
Railroad bridge, Clear and Indian creeks	848	C. & G. W. Ry.
Mingo	857	C. & G. W. Ry.
Divide between Indian creek and Skunk river	971	C. & G. W. Ry.
Valeria	876	C. & G. W. Ry.
Skunk river bottom W. Co. line	831	C. & G. W. Ry.
Mitchellville	905	C., R. I. & P. Ry.
Colfax	765	C., R. I. & P. Ry.
Skunk river at railroad bridge	753	C, R. I. & P. Ry.
Newton	916	C, R. I & P. Ry.
North Skunk railroad crossing	815	C., R. I. & P. Ry.
Kellogg	810	C., R. I. & P. Ry.
Rock creek	836	C., R. I. & P. Ry.
Sugar creek	877	C., R. I. & P. Ry.
Newberg	1063	Iowa Central Railway.
Murphy	846	Iowa Central Railway.
Sully	943	Iowa Central Railway.
Lynnville Junction	938	Iowa Central Railway.
Monroe railway station	909	Barometer.
Prairie City	920	Barometer.

DRAINAGE.

In the table of elevations the relative altitudes of different parts of the county are indicated. It is seen that the surface has a slight slope to the south. Baxter near the north border of the county, situated on the divide between the North Skunk and the Skunk river systems, is 124 feet higher than the town of Monroe, which is near the southern edge of the county and on the watershed between the Skunk and Des Moines systems. The slope of the last divide is shown by the difference in level between Prairie City, with an altitude of 920 feet, and Monroe with an elevation of 909 feet above tide. It is here but slightly over one foot per mile. From Baxter to Monroe it is more than six feet per mile.

The highest point in the county for which authentic record is to be had is near the northeast corner. Here the divide on which Newberg is situated is approximately 1063 feet above sea level. At the Chicago Rock Island and Pacific railway bridge over Sugar creek the altitude is 877 feet, while the general upland is about 100 feet higher. The divide between North Skunk river and Elk creek, in Lynn Grove township, which is followed by the Iowa Central Railroad, has an elevation of about 940 feet. The north-south slope of the surface in this part of the area is therefore essentially six feet to the mile.

Viewed broadly, Jasper county consists of a fairly level loess-Kansan plain, gently sloping to the south; into which the streams have worn their valleys. Truncating the northwest corner of this plain is the area of subdued topography, the Wisconsin drift; while the northeast corner may perhaps be somewhat modified by the Iowan till sheet. The fact, however, that the principal streams have northwest-southeast courses indicates that the inclination of the drift surface had little to do with determining their direction of flow. They, in general, show evidence of having been established in their present positions previous to the advent of the Kansan glacier. The smaller tributary branches are superimposed and have cut their channels in the materials of the drift alone.

The drainage of the county is effected largely by Skunk river, the North Skunk, and their branches. An area in the

southwest corner, embracing approximately a township and a half, discharges its surplus through several small tributaries directly into the Des Moines, which flows through Marion county a few miles to the south. Tributaries of the Iowa river encroach on the northeast corner of the county, and drain a few square miles in Hickory Grove township. The loess-Kansan area is perfectly drained, the head branches to the tributaries of the competing streams frequently interlocking across the divides. The Wisconsin drift is not so completely drained, and upland ponds and sloughs are not uncommon.

Drainage from any land area is said to be perfect when all portions of its surface have such slope that water that has fallen upon it will by gravity flow from it. It might be further added that the water thus flowing from the land is gathered into well established waterways or stream systems and carried outside of the area in question.

The amount of water draining from the land through surface flow is known as the "run off," and its quantity depends upon the amount of rainfall and on the character of the land itself. Water falling as rain is disposed of in three ways, viz., by evaporation into the atmosphere, by absorption into the earth, and by flowing directly into the streams. The quantities disposed of in these different ways vary according to several factors the most important of which are, angle of slope, geological structure of the rocks, character of the soil, presence or absence of vegetation, and nature of the rainfall. It is apparent that the greater the declivity the greater will be the tendency for water to flow at once into the streams during periods of precipitation. If the country rock is of a dense and non-porous nature the amount absorbed is less than if it is porous or has a jointed structure. Open-textured soils will not only take in moisture with avidity but will also give it up readily when conditions are favorable for evaporation. The denser clay soils absorb water slowly and by capillarity retain it longer, both against evaporative influences and the tendency to pass into the underlying rock strata, than do soils of open texture. It may be said that in general vegetation is a conserver of moisture. It not only prevents rapid and immediate

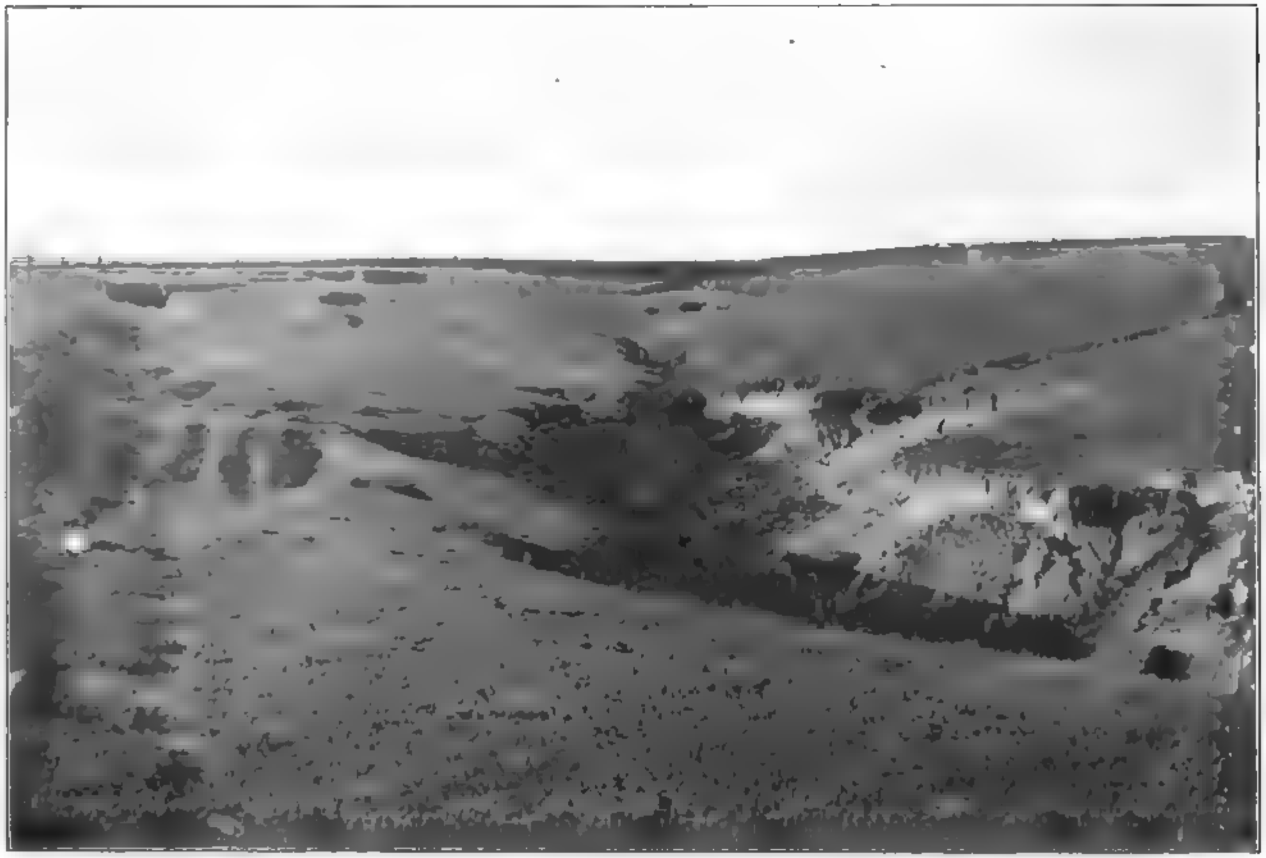

PLATE V. Trenching in the loess and Kansan drift, one-half mile east of Kellogg, in section 23, Kellogg township.

discharge, but accumulated vegetable mould serves as a damp surface blanket to the soil beneath; retaining the moisture and hindering evaporation. It is evident again that the run off is influenced by the nature of the rainfall. A quiet, light, continued rainfall will permit of far greater absorption by the soil and rocks than a heavy, torrential one. Where the total quantity of precipitation is perhaps moderate, economically it may be ample or deficient according to whether it falls in a few heavy showers or is distributed in the different seasons as numerous periods of light rainfall.

In the area under consideration, the slopes, from the standpoint of the disposition of the rainfall, may in general be considered moderate and the soils as a rule of the more porous types. This last is especially true of the loess soils, while perhaps less so of the drift and alluvial varieties. Assuming an average rainfall of thirty-one inches* for this county, there are falling upon its surface of approximately 460,800 acres, more than fifty-one billion cubic feet of water, or more than one billion and a half tons per year. Of this vast quantity, more than six hundred million tons pass into the drainage streams each year.† This is forty per cent of the total rainfall, or somewhat in excess of twelve inches. These figures, it is believed, may be accepted as representing the average run off from drift laden regions in central Iowa where the drainage lines are fully developed, as they are over essentially all of Jasper county.

The remaining nineteen inches of precipitation are absorbed by the rocks and soils from which the moisture for plant growth is drawn. Of this portion, however, a variable percentage is returned to the atmosphere by evaporation, while a greater or less amount sinks into the earth and drains away through subterranean passages. The actual volumes of water disposed of in these different ways are difficult of computation.

*Average of records for eight years, 1893 to 1900, inclusive, at Newton, as reported to the Weather Bureau by Mr. A. Lufkin. The extremes are 19.64 inches in 1894, and 44.9 inches in 1896.

†The data for this estimate are figures for the area of catchment and volume of flow in North Skunk, Skunk and other Iowa rivers, taken from Tenth Census, Water Power of U. S., Vol. XVII, p. 98. Also Water Supply and Irrigation paper No. 80, U. S. G. S., 1903.

The distribution of the precipitation by seasons, at Newton, is indicated in the following table. The three years, 1899, 1900 and 1901 are selected as representative. The data are compiled from the Monthly reports of the Iowa Weather and Crop service:

Months.	1899	1900	1901	Average.
January	.86	.37	1.00	.74
February	.75	1.36	1.80	1.30
March	.74	3.55	3.47	2.59
April	4.52	2.79	1.94	3.08
May	6.61	4.03	2.24	4.29
June	2.00	6.35	3.58	3.98
July	2.30	4.98	2.89	3.39
August	4.51	6.11	1.30	3.97
September	.50	3.73	2 98	2.40
October	.61	4.23	1 80	2.21
November	1.52	1.60	.83	1.32
December	2.34	.97	1.32	1.54
Totals	27.26	40.07	25.15	30 81

Snowfall is estimated as rain. While the actual amount of moisture is moderate, its distribution is such that it is ample for the growth of a variety of crops. This is of course made possible only because of the favorable range of the attendant weather conditions, among which the temperature is of chief importance.

Skunk river.—This river flows diagonally southeastward across the county, entering near the middle of the west boundary and making its exit into Marion county some four miles east of the middle of the southern boundary. It is the largest water way in the region, and with the branches that pay tribute to it, drains not less than two-thirds of the county. The fall of the river from Ames, in Story county, to Rome, in Henry, averages two and one-half feet per mile.* The estimated volume of water passing a point formerly known as Vowell's near the present town of Metz is eighty † cubic feet per second, amounting to nearly two billion gallons in the ordinary year. The flow of the river varies from season to

* Water Supply and Irrigation paper U. S. G. S., No. 44, p. 79.
† Water Power in U. S. Tenth Census, Vol. XVII, 1880, pt. II, p. 98.

season with the rainfall, and is not to be relied upon from year to year. Rapid rises are common during which its flood plain from border to border becomes one broad stream of water. Such inundation is not so common now as in earlier years.

The width of the valley of Skunk river ranges from one mile and a quarter to nearly three miles. Within the Wisconsin drift it is somewhat narrower than its prevailing width elsewhere. In its course through the Kansan drift area two points where the valley is much narrowed are notable. On entering Mound Prairie township the river flows close to the southwest side of the valley and exposes Coal Measure strata for some distance in sections 4 and 5. From this point it is deflected to the opposite valley wall, exposing, in section 3, the Des Moines shales and sandstones. The minimum width of the valley is in this region one and a quarter miles, while, both above and below, it rapidly broadens to from two to three miles. The constriction at this point appears to be due to the more resistant strata through which the stream has been compelled to cut its channel. The Coal Measures here stand higher and represent an outlier which disappears back from the river in both directions. Again in the southern part of Palo Alto township the valley is narrowed to about one mile across the belt of Red Rock sandstone. The constriction is here even more noticeable, and the river flows for one mile between Palo Alto and Fairview townships at the foot of abrupt bluffs of this rock capped with loess. Escarpments of brown, heavy bedded sandstone are also found to the east both above and below Reasnor. The narrowness of the valley can be accounted for only by the resistance to erosion offered by the comparatively hard sandstone.

The flood plain of the river is universally covered with alluvium. Borings made in the valley show it to be filled with alternating strata of river silt, sand, and occasionally gravel. The thickness of these layers above the country rock has not been ascertained. In no instance was record found of any borings in the valley penetrating to the indurated rock. At the locations cited, where the width of the valley is much lessened by the harder strata in its walls, the depth below the

present flood plain seems considerable and has not been reached in the valley proper. These facts indicate that the stream, in the earlier stages of its development, possessed great erosive power, at which time it channeled deeply into the Coal Measures, and, that since, through a change of level, it has partially filled in its old, and probably preglacial, valley. It is further suggested that the surface flow of the river today does not by any means represent all of the water drained away through its course. It may be confidently assumed that a considerable proportion of its discharge, moves beneath the surface in the porous sand and gravelly strata. This probably accounts for its uncertain flow, and for the fact that in certain seasons portions of it may even go dry.

As has been mentioned, a partial filling of Skunk river valley has taken place in the Wisconsin drift area. The deposits of material made by the Wisconsin glacier in Jasper county seem to have been light and were not accompanied by pronounced water action. The pre-Wisconsin banks are perfectly evident, and are covered with a thin deposit of the later drift. Typical Wisconsin material likewise occurs on the floor of the valley as low, irregular mounds or ridges. These often extend well out into the main depression. They may be observed all along the south border in Washington, and are conspicuous below Valeria in Poweshiek township.

The course of the river is in general meandering from one side of its broad flood plain to the other. As is common with the most of the rivers of Iowa that have a northwest-southeast direction of flow, the breadth of flood plain to the northeast side is usually greater than that to the southwest of the stream. In the lower part of its course in the county its channel is often extremely sinuous and unstable. In places, as in section 29, Palo Alto township, it may even fork or anastomose, as one channel becomes unable to accommodate the flow. Sand-bars are a common feature, although not so important as are the deposits of sand and silt to be found at numerous points, chiefly to the northeast side of the river.

The principal branches belonging to the Skunk river system, and which join this river in the county, are Indian, Prairie, Cherry and Squaw creeks. Those tributary streams of importance belonging to the system which join it outside of the county are Elk creek and North Skunk river.

Indian creek.—Indian creek, with several small branches from the north, effects the drainage of the northwest corner of the county, north of Skunk river. It is second in size only to the Skunk itself, and joins the latter stream just east of Colfax, where the blending of the two flood plains is responsible for the unusual breadth of bottom land in the southern portion of Sherman township. Above its confluence and outside of the Wisconsin drift, the width of the valley ranges from one mile to a mile and one-half. The stream is meandering in its valley and branches about three miles above its union with the Skunk, entering this river through two channels at points more than one mile apart. The width of the valley appears to be somewhat out of proportion to the size of the present stream. Within the Wisconsin drift area the valley is much constricted, and has been partially filled by the drift deposits. Where it enters from Polk county its flood plain is one mile in width. In section 28, Clear Creek township, Indian creek has been diverted from its pre-Wisconsin course, and from the northwest corner of this section to the middle of section 24, it flows in a narrow, gorge-like, drift bordered valley which it has excavated since the close of the Glacial period. The stream is here bounded by prominent drift hills to the east, and similar, though less conspicuous, elevations separate it from the old depression less than one mile to the southwest. This last depression can still be clearly traced, leading in both directions into the valley now occupied by the stream.

The most important tributaries to Indian creek are Silver and Wolf creeks, which join the parent stream in the Wisconsin area; and Clear creek with its branch, Mud creek, which follow courses parallel to and outside the border of the later drift. Silver and Wolf creeks are small streams following depressions excavated since the deposition of the Wisconsin drift. They have narrow flood plains that extend but short

distances toward their heads, and the few branches leading into them have eroded sharp V-shaped gorges in the glacial till. The beds of these streams are often very gravelly and the surfacing of alluvium on the flood plains is prevailingly thin.

Clear creek is a much older and longer established stream, its course being entirely in the loess-Kansan area. It has a well developed flood plain, and has reached base level throughout its course in the county. Broadening of the valley is now rapidly going on. The creek swings from wall to wall in a series of bold curves and is gouging out the sides of its valley. Much of the flood plain is thickly wooded, and bayous and cutoffs are common features. The alluvial material in this valley is of considerable depth, as it is also in the channel of Indian creek. Wells in Independence township are reported to have struck "slate" at forty feet, the upper strata being sand and silt. There are indications also that the river has at times exposed the shales where it impinges against its valley wall in western Independence township, but no outcrops are now visible.

Mud creek is a small tributary which takes its rise in the poorly drained area of the Wisconsin drift. It breaks through the drift margin at the south border of section 1, Clear Creek township, and thence flows in a narrow, alluvial valley to its union with Clear creek in section 24.

In northern Independence township Clear creek has deepened its valley 100 feet below the upland to the east; while to the west the adjoining hills rise 135 feet above the water. In section 35, Clear Creek township, it runs seventy feet below the hills to the east. The hills of Wisconsin drift, where Mud creek enters the county, have an elevation of eighty to ninety feet above the stream bed. At the south edge of section 1, where this creek leaves the Wisconsin area, they rise 110 feet, while the loess-covered Kansan to the east is but sixty-five feet above the water. Within the newer drift, Wolf creek has excavated a valley sixty feet below the level of the drift plain, measured in section 10. In section 17, the water level of Wolf creek is 140 feet below adjacent hills to the north. From

the north boundary of section 10 to the south edge of section 17, this stream has a fall of forty-five feet, being approximately eighteen feet per mile.

At the west county line Indian creek has a depression of 110 feet. The hills in section 33, Clear Creek township, rise fifty to sixty-five feet above the flood plain. Indian creek, at the bridge on the east side of section 12, Poweshiek township, is 120 feet below the hills adjoining, both to the north and south.

FIG. 22.—Rapid erosion in Wisconsin drift. This gully, twenty-five feet deep, has been excavated in the past six years.

Prairie and Cherry creeks are streams of some importance flowing into Skunk river, and draining areas in Newton and Sherman townships principally. They have well developed flood plains in the larger portion of their courses, and have accomplished a considerable amount of downward cutting. West of the town of Newton, Cherry creek has exposed the shales and sandstones of the Coal Measures. Here the creek flows 125 feet below the upland. Its average depression is

about one hundred feet. Both of these streams have high gradients, and their headwaters are vigorously extending their drainage territory.

Squaw creek is a branch of minor importance entering Skunk river west of Colfax. It receives some small tribute from the Wisconsin drift area. In section 8, Washington township, one of its feeders has been diverted from its former course by the railroad. An example of unusually deep and rapid trenching is here to be observed. Within a few years this small stream has channeled into the Wisconsin drift in places twenty-five to thirty feet, forming a narrow gorge with precipitous walls for a distance of about one-third of a mile leading into the valley of the Skunk river. See figure 22.

Elk creek joins the Skunk river in Mahaska county, and drains essentially two townships, Elk Creek and Buena Vista. It has a mature valley, and numerous branches extend back to the divides towards the northeast and southwest. The latter commonly occupy sharp ravines or gullies carved in the loess and Kansan drift. Where Elk creek traverses the thin belt of Red Rock sandstone, in Buena Vista township, exposures of this rock occur, and some quarrying has been done near Murphy.

With the exception of Indian creek, North Skunk river is the largest affluent of the Skunk river in the county. It drains, however, a much larger territory than Indian creek, and with its various tributaries it is fully as important as is the parent stream. It maintains a uniform southeasterly direction from its entrance at the northwest corner of Malaka township to its exit from the county in the eastern border of Lynn Grove township. Its branches invade ten of the nineteen civil townships in the county, and drain more than one-third of the total area.

North Skunk river has a flood plain varying in width and ranging from less than one-fourth of a mile in Malaka township to more than three-fourths of a mile at points in the lower part of its course. The valley borders are not always well defined. From the general upland the flood plain is reached by gradual slopes, with low ridges, which often appear to extend into the valley, or even stand quite isolated in the depression itself.

These are always capped with loess and in position suggest portions of an earlier flood plain deposit that the river has since failed to remove. The material beneath the loess, as shown where the river has dissected these deposits, consists of iron-stained sand and gravel, in most places somewhat stratified. A section showing this character may be observed in the southeast ¼ of section 5, Richland township, where a thickness of fifty feet of a sandy, iron-stained drift deposit, capped with thirteen feet of loess, is exposed by the river. In other places, the material is typical, weathered bowlder clay. No evidence of terraces now exists, but such a feature may be obscured by subsequent loess deposition.

The characteristics of the valley in general appear to indicate the putting down of large quantities of partially sorted glacial detritus, probably during the retreat of the Kansan ice when the stream was overloaded. The removal of this material has since been but partially accomplished by the river. The bluffs bounding the valley rise gradually to fifty or sixty feet above the water. They are covered with loess and are more prominent along the west border.

The only tributaries of considerable size join North Skunk river from the east. In order, from the north they are, Snipe, Alloway, Rock and Sugar creeks, the last one meeting the parent river outside the borders of Jasper county. All of these streams have narrow flood plains which are developed but a few miles back from their mouths. Rock and Sugar creeks have cut more deeply, and they, with their branches, have made the relief of portions of Rock Creek township very pronounced. In section 7 Rock creek cuts through the Red Rock sandstone, and quarrying has been done at several points on both sides of the stream. To the west of North Skunk river the divide lies quite close to the channel, there being no tributaries of any length.

Des Moines river.—This system is represented by four small streams which together drain a little more than the southwestern township of the county. A curve in the course of Camp creek causes the stream to encroach upon Jasper county near the southwest corner of Des Moines township. It enters and

leaves the township at points not more than one mile apart. The stream has a well defined valley, but the area it drains is small. Walnut, Calhoun, Prairie and Brush creeks should also be mentioned as belonging to the Des Moines system. Walnut has done considerable downward cutting, and the Coal Measures are exposed at various places along its course. Coal is mined near the north border of section 22, Des Moines township. The shales and sandstones are also exposed along Calhoun creek, where coal has been mined in years past. West of the town of Monroe, along Brush creek, the Coal Measure clays are very near the surface, and are utilized at the Orcutt clay works. The area drained by this stream is insignificant.

STRATIGRAPHY.

General Relations of Strata.

The formations represented in Jasper county belong to two geologic groups which are separated by an unconformity. This break in the continuity of the strata indicates the lapse of an enormous period of time, equal in length to the whole of the Mesozoic era and the Tertiary period of the Cenozoic. During this interval the area under consideration was probably a land surface and subjected to the action of the denuding agents. The surface of the Paleozoic rocks was profoundly eroded previous to the deposition of the Pleistocene strata during the recent or Cenozoic era. The major time divisions represented therefore are the Paleozoic and the Cenozoic.

The strata deposited during these long and widely separated divisions of geologic time are classified in the following table:

GROUP.	SYSTEM	SERIES	STAGE	FORMATION
Cenozoic	Pleistocene	Recent		Alluvium Sands and silts
		Glacial	Wisconsin	Drift
			Iowan	Loess and bowlders
			Kansan	Drift
Paleozoic	Carboniferous	Upper Carboniferous or Pennsylvanian	Des Moines	Red Rock sandstone Shales and sandstones
		Lower Carboniferous or Mississippian	Saint Louis?	
			Kinderhook	Limestones and sandstones

The rock strata lying deeper than those included in the above table have been explored at but one point in the county. The Newton deep well penetrates to the Maquoketa shales of the Ordovician. No other drillings that go beyond the Mississippian were found. In the northeastern portion of the area wells are seldom sunk to indurated rock. Deep wells and the drillings of prospectors, however, invariably encounter a hard limestone overlain usually with a greater or less thickness of the shale or sandstone strata of the Des Moines stage. Few borings in the western part of the county pass through the Coal Measures.

The attitude of the Paleozoic strata is monoclinal, dipping at a low angle to the south and west. Aside from the small triangular area in the northeast corner, which is detached by projecting the line of strike of the Kinderhook in Marshall county, the county is probably completely covered by the sands and shales of the Des Moines stage of the Upper Carboniferous series. These rest presumably upon the Kinderhook rocks in the northern part of the county; while over the remainder of

the area deposits of the Saint Louis stage form the floor of the Coal Measures.

Figure 28 represents a geological section across Jasper county from Prairie City, in the southwestern part, to Newberg in the northeast, showing the attitude and relations of the different formations. The drawing is on a vertical scale of 350 feet to one inch.

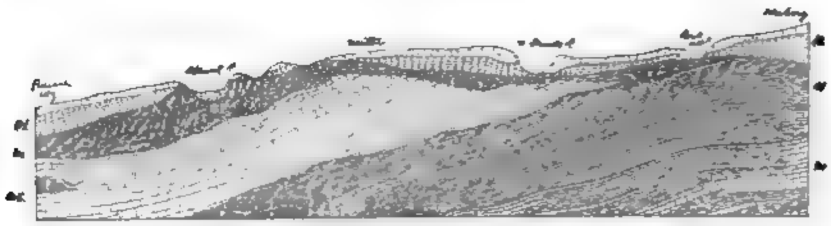

FIG. 28. Geological section from Prairie City to Newberg.
Pl. Pleistocene. St. L. Saint Louis. Ds. Des Moines.
Kd. Kinderhook. Dv. Devonian.

The following records of deep drillings will furnish a general idea of the thickness and depth of the various formations penetrated. The record of the Grinnell well, located in Poweshiek county, some two miles to the east of Jasper county, is also given:

*Grinnell Well Record.**

FORMATION.	THICKNESS.	DEPTH.	A. T.
Pleistocene	212	212	816
Saint Louis and Kinderhook	358	570	[illegible]
Devonian	370	940	88
Silurian	260	1,200	-172
Maquoketa	120	1,320	-292
Galena-Trenton	380	1,700	-672
Saint Peter	40	1,740	-712
Upper Oneota (?)	262	2,002	-974
New Richmond (?) at	...	2,092	......

The glacial deposits are here 212 feet in thickness, and, according to Mr. Jones, rest practically on the upper surface of the Saint Louis. This would make the base of the Coal Measures approximately 816 feet A. T.

*Iowa Geol. Surv., Report on Artesian Wells, Vol. VI, p. 291.
Jones, A. J: Proc. Io. Acad. Sci., Vol. II, p. 82, 1894.

COLFAX WELLS.

In the town of Colfax and vicinity there are more than a dozen wells, all drawing their supply from the same horizon, and ranging about three hundred feet in depth. The aquifer appears to be in the Saint Louis limestone. No accurate records of these wells are available, so that the depth at which the Saint Louis is reached can not be definitely stated. The following is the general sequence, as given from memory by one who has had to do with the sinking of several of the wells:

5.	Sand and drift clay	80	feet.
4.	Slate	18	"
3.	Coal	1.5	"
2.	Sandstone, shale and sulphur bands	198	"
1.	Limestone, about	18	"

From this record the Coal Measures are about 217 feet in thickness, and the top of the Saint Louis limestone is about 544 feet above tide. From Grinnell, twenty-eight miles to the east, to Colfax, the dip thus approximates nine and one-half feet to the mile, between six and seven minutes of angle.

A series of coal prospect drillings put down in sections 28, 31 and 32 of Independence township, by Mr. W. P. Rippey, penetrated the following beds:

		FEET.
8.	Yellow to gray clay	0 to 20
7.	Blue bowlder clay	2 to 6
6.	Sand and gravel	80 to 90
5.	Soapstone, slate or sandstone	0 to 4
4.	Clay or slate, lime rock and sulphur stone	30 to 40
3.	Coal	.5 to 1
2.	Sandstone and sometimes "red rust" resting on hard rock.	
1.	Hard rock (limestone ?)	

The "hard rock" is probably the basement limestone and represents either the Saint Louis strata or the Kinderhook; more likely, perhaps, the former, as the Saint Louis limestone has been recognized by Dr. Bain in a drilling three miles north of Mitchellville, in the edge of Polk county*. This stratum has been penetrated to a depth of nearly 100 feet, in a hole sunk

*Geology of Polk County, Ann. Rep. Iowa Geol. Surv., Vol. VII, p. 322.

near the northeast corner of section 32 of Independence township, where it was found to consist of alternating layers of hard and soft rock. Occasionally a thin band is encountered, which is so resistant that it is difficult to drill through it. The presence of these bands is perhaps suggestive of the Kinderhook, as resistant layers of chert are a constant feature of that formation where it is exposed in Marshall county.

Mississippian Series.

Representatives of the Lower Carboniferous or Mississippian series, of the Carboniferous system are nowhere exposed in the county. In Marshall county to the north exposures of the Kinderhook strata are found along Timber creek near Ferguson, between five and six miles from the Jasper county line. The Coal Measures in Marshall county rest upon the Kinderhook beds; strata belonging to the Saint Louis stage being in general absent. As has been noted earlier, the Saint Louis limestone is recognized in the Grinnell deep well section. Mr. A. J. Jones* assigns to it a thickness of fifty-eight feet, and refers underlying argillaceous beds to the Augusta stage. Professor Norton, in his report on the Artesian Wells of Iowa, notes that the Saint Louis limestone is present, but does not separate this stage from the preceding one. The limestone in which the first flow of water is obtained at Newton is referred by Professor Norton† to the Saint Louis. This authority also expresses the probability that the source of supply in the Colfax wells is in the same formation.

The strata of the Saint Louis stage are typically exposed in Mahaska and Marion counties. In the latter a thickness of 270 feet of Mississippian rocks above the Kinderhook was penetrated in the deep well at Pella. At Mitchellville, in Polk county, Bain‡ has with some doubt referred forty feet of strata to the Saint Louis stage; while to the westward the formation rapidly thickens as the records of the Greenwood Park well and other deep drillings in and near Des Moines go to show.

*Iowa Acad. Sci., Vol. II, p. 82, 1894.
†Artesian Wells of Iowa. Iowa Geol. Surv., Vol. VI, p. 292.
‡Ann. Rep. Iowa Geol. Surv., Vol. VII, p. 291.

Taking a somewhat broader survey of the relations between the Coal Measures, the Saint Louis strata and the underlying rocks, it is found that, at no place in the counties to the southeast, along the strike of these strata, where the geology has been studied in detail, has the absence of the Saint Louis limestone been observed. To the northwest across Marshall and Hardin counties the rocks of the Des Moines stage rest upon beds older than the Saint Louis. In Webster and Humboldt counties the Saint Louis limestone is again recognized. It is thus seen that over the area mentioned the materials composing the Saint Louis strata were either never deposited, or were worn away before the Coal Measures were laid down. The first assumption seems probable in view of the fact that where observed in the Grinnell and Mitchellville wells these strata are thin in comparision with the corresponding strata farther south and west. A gradual thinning or wedging of the Saint Louis deposits is indicated, and beyond its limits the Des Moines strata overlap, and rest upon the older formations.

In Jasper county the area underlain by the Kinderhook rocks can not be definitely outlined as these materials are deeply buried beneath the glacial deposits; nor are any strata referable to the Augusta known. The area outlined as Kinderhook on the map is determined by projecting the line of the strike from outcrops in Marshall county. Neither can the border of the Saint Louis deposits be traced. It is not believed to be the country rock in any part of the county, but the interest that attaches to it comes from its wedging out and giving way to the Kinderhook as the floor upon which the Coal Measures rest. The line of overlap apparently has a northwest-southeasterly course, and can not lie far within the limits of the Coal Measures themselves.

Pennsylvanian Series.

DES MOINES STAGE.

All of the Paleozoic rocks exposed in the county belong to the Des Moines stage of the Upper Carboniferous series. As indicated on the Geological map, they cover the entire county, with the exception of the triangular area of Kinderhook in the extreme northeast corner. They consist of interstratified shales, sandstones, coal and occasional thin beds of limestone. Their character varies rapidly from place to place. With the exception of the Red Rock sandstone, none of the strata are sufficiently persistent over any considerable area to be relied upon in correlation. The shales are prevailingly sandy and grade laterally into argillaceous sandstones. The sandstone layers are in places calcareous and, especially in connection with certain coal seams, pass into arenaceous limestones. Limestones of the darker colored variety occur as lenses and concretionary masses in some of the coal basins. The coal beds are likewise of limited lateral extent, and are not found at any constant horizon.

The thickness of the Des Moines strata varies from nothing in the northeast to nearly 200 feet in the vicinity of Colfax. No data are to be had as to their thickness in the southern part of the county. A prospect hole three miles north of Mitchellville*, in the border of Polk county, passes through 160 feet of Coal Measure strata. In Marion county to the south, B. L. Miller† estimates the maximum thickness of the Coal Measures as 600 feet. Because of the uneven floor upon which they rest, however, their thickness will range within broad limits in even small areas.

In Jasper county the rocks of the Des Moines stage are universally covered with drift. Previous to the deposition of the glacial materials the land surface was irregular, and erosion has since gone on through long periods of time. The depth beneath the surface at which the Coal Measures now lie has been

* Geology of Polk County, Bain, Iowa Geol. Surv., Vol. VII, p. 322.
†Geology of Marion County, Miller, Iowa Geol. Surv. Vol. XI, p. 147.

determined largely by these factors. Exposures are not numerous, as a rule, but are found fairly well distributed over the southern half of the county. Although the best sections are to be observed along stream ways, natural outcrops are not lacking over the uplands away from the streams.

The following section is found east of the wagon bridge over Skunk river in section 32, Elk Creek township, where the river impinges against the east wall of its valley:

		FEET.	INCHES.
5.	Loess and Kansan drift	4	
4.	Shale, sandy and carbonaceous, and interstratified with thin bands of sandstone; plant stems preserved in sandstone	8	
3.	Sandstone, brown, compact		7
2.	Coal	1	6
1.	Fire clay and talus, to water	10	

The strata are here exposed for a distance of three hundred feet and have the attitude of a low anticline, the section given being measured near the center of the arch. The coal seam ranges from eight inches to one and one-half feet. The band of sandstone above the coal is not constant, being frequently replaced by arenaceous shale.

On the county line road, near the middle of the south side of section 31, Lynn Grove township, the Coal Measures, capped with drift and loess, outcrop in the following sequence:

		FEET.	INCHES.
5.	Clay shale, light in color, with sandstone and iron-stained concretions	17	
4.	Carbonaceous shale	3	
3.	Coal blossom		8 to 9
2.	Obscured by talus	30	
1.	Sandstone, shattered, iron-stained (in gutter at south side of road)	4	

Along the North Skunk river, from Lynnville northward into Richland township, the Coal Measures outcrop at several points. In section 3, Lynn Grove township, and section 33, Richland, along small branches leading into the Skunk river valley, the shales are exposed. Along the east side of the river, near the middle of the west side of section 35, Richland township, a fif-

leaves the township at points not more than one mile apart. The stream has a well defined valley, but the area it drains is small. Walnut, Calhoun, Prairie and Brush creeks should also be mentioned as belonging to the Des Moines system. Walnut has done considerable downward cutting, and the Coal Measures are exposed at various places along its course. Coal is mined near the north border of section 22, Des Moines township. The shales and sandstones are also exposed along Calhoun creek, where coal has been mined in years past. West of the town of Monroe, along Brush creek, the Coal Measure clays are very near the surface, and are utilized at the Orcutt clay works. The area drained by this stream is insignificant.

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The formations represented in Jasper county belong to two geologic groups which are separated by an unconformity. This break in the continuity of the strata indicates the lapse of an enormous period of time, equal in length to the whole of the Mesozoic era and the Tertiary period of the Cenozoic. During this interval the area under consideration was probably a land surface and subjected to the action of the denuding agents. The surface of the Paleozoic rocks was profoundly eroded previous to the deposition of the Pleistocene strata during the recent or Cenozoic era. The major time divisions represented therefore are the Paleozoic and the Cenozoic.

The strata deposited during these long and widely separated divisions of geologic time are classified in the following table:

Mr. J. D. Whitney* mentions sandstone outcropping in "low ledges along the North Skunk, below the junction with Rock creek." These are referred by him to the same horizon as the heavy sandstone exposed on Rock creek and on North Skunk river, east of Kellogg. The present study indicates that the sandstone noted by Whitney should be referred to the coal-bearing strata, while the sandstone along Rock creek belongs to the Red Rock sandstone formation which will be considered later.

About ten feet of sandstone are exposed near the middle of section 16, Richland township, on the west bank of the river a short distance south of the bridge, where a considerable amount seems to have been quarried, although no work has been done here for years. This rock probably belongs to the Red Rock sandstone.

In the region to the west of the belt of Red Rock sandstone, exposures are found along Skunk river below the junction of Indian creek, along Cherry creek west of Newton, and at various points in the northern part of Palo Alto township. In the southwest corner of the county the small streams, Brush, Calhoun and Walnut creeks, have exposed the Coal Measures along their courses.

A well at the McAllister clay plant in Newton, affords the following section:

		FEET.
4.	Soil, yellow clay and blue gravelly clay	100
3.	Sandstone	10
2.	Soapstone, clean; slate; one inch coal; fire clay, so-called	100
1.	Sandstone	15

One-half mile north of the Chicago Rock Island & Pacific railroad bridge over the Skunk river, in section 10 of Mound Prairie township, where the river runs close to the east valley wall, the following sequence of strata has been observed in coal mining operations, but the thickness of the various members can not be given because of their variability. Here a heavy mantle of Kansan drift and loess overlies the Coal Measures. The indurated rocks are frequently separated by a few feet of

*Geol. Surv. of State of Iowa, Vol. I, part 1, p. 272, 1858.

leaves the township at points not more than one mile apart. The stream has a well defined valley, but the area it drains is small. Walnut, Calhoun, Prairie and Brush creeks should also be mentioned as belonging to the Des Moines system. Walnut has done considerable downward cutting, and the Coal Measures are exposed at various places along its course. Coal is mined near the north border of section 22, Des Moines township. The shales and sandstones are also exposed along Calhoun creek, where coal has been mined in years past. West of the town of Monroe, along Brush creek, the Coal Measure clays are very near the surface, and are utilized at the Orcutt clay works. The area drained by this stream is insignificant.

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			Iowan	Loess and bowlders
			Kansan	Drift
Paleozoic	Carboniferous	Upper Carboniferous or Pennsylvanian	Des Moines	Red Rock sandstone Shales and sandstones
		Lower Carboniferous or Mississippian	Saint Louis?	
			Kinderhook	Limestones and sandstones

The rock strata lying deeper than those included in the above table have been explored at but one point in the county. The Newton deep well penetrates to the Maquoketa shales of the Ordovician. No other drillings that go beyond the Mississippian were found. In the northeastern portion of the area wells are seldom sunk to indurated rock. Deep wells and the drillings of prospectors, however, invariably encounter a hard limestone overlain usually with a greater or less thickness of the shale or sandstone strata of the Des Moines stage. Few borings in the western part of the county pass through the Coal Measures.

The attitude of the Paleozoic strata is monoclinal, dipping at a low angle to the south and west. Aside from the small triangular area in the northeast corner, which is detached by projecting the line of strike of the Kinderhook in Marshall county, the county is probably completely covered by the sands and shales of the Des Moines stage of the Upper Carboniferous series. These rest presumably upon the Kinderhook rocks in the northern part of the county; while over the remainder of

the area deposits of the Saint Louis stage form the floor of the Coal Measures.

Figure 23 represents a geological section across Jasper county from Prairie City, in the southwestern part, to Newberg in the northeast, showing the attitude and relations of the different formations. The drawing is on a vertical scale of 350 feet to one inch.

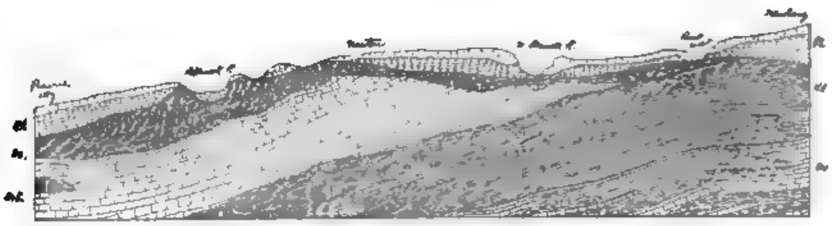

FIG. 23. Geological section from Prairie City to Newberg.
Pl. Pleistocene. St. L. Saint Louis. Ds. Des Moines.
Kd. Kinderhook. Dv. Devonian.

The following records of deep drillings will furnish a general idea of the thickness and depth of the various formations penetrated. The record of the Grinnell well, located in Poweshiek county, some two miles to the east of Jasper county, is also given:

*Grinnell Well Record.**

FORMATION.	THICKNESS.	DEPTH.	A. T.
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Upper Oneota (?)	262	2,002	-974
New Richmond (?) at	...	2.092	....

The glacial deposits are here 212 feet in thickness, and, according to Mr. Jones, rest practically on the upper surface of the Saint Louis. This would make the base of the Coal Measures approximately 816 feet A. T.

*Iowa Geol. Surv., Report on Artesian Wells, Vol. VI, p. 291
Jones. A. J: Proc. Io. Acad. Sci., Vol II, p. 81, 1894.

COLFAX WELLS.

In the town of Colfax and vicinity there are more than a dozen wells, all drawing their supply from the same horizon, and ranging about three hundred feet in depth. The aquifer appears to be in the Saint Louis limestone. No accurate records of these wells are available, so that the depth at which the Saint Louis is reached can not be definitely stated. The following is the general sequence, as given from memory by one who has had to do with the sinking of several of the wells:

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2.	Sandstone, shale and sulphur bands	198 "
1.	Limestone, about	18 "

From this record the Coal Measures are about 217 feet in thickness, and the top of the Saint Louis limestone is about 544 feet above tide. From Grinnell, twenty-eight miles to the east, to Colfax, the dip thus approximates nine and one-half feet to the mile, between six and seven minutes of angle.

A series of coal prospect drillings put down in sections 28, 31 and 32 of Independence township, by Mr. W. P. Rippey, penetrated the following beds:

		FEET.
8.	Yellow to gray clay	0 to 20
7.	Blue bowlder clay	2 to 6
6.	Sand and gravel	80 to 90
5.	Soapstone, slate or sandstone	0 to 4
4.	Clay or slate, lime rock and sulphur stone	30 to 40
3.	Coal	.5 to 1
2.	Sandstone and sometimes "red rust" resting on hard rock.	
1.	Hard rock (limestone ?)	

The "hard rock" is probably the basement limestone and represents either the Saint Louis strata or the Kinderhook; more likely, perhaps, the former, as the Saint Louis limestone has been recognized by Dr. Bain in a drilling three miles north of Mitchellville, in the edge of Polk county*. This stratum has been penetrated to a depth of nearly 100 feet, in a hole sunk

*Geology of Polk County, Ann. Rep. Iowa Geol. Surv., Vol. VII, p. 322.

near the northeast corner of section 32 of Independence township, where it was found to consist of alternating layers of hard and soft rock. Occasionally a thin band is encountered, which is so resistant that it is difficult to drill through it. The presence of these bands is perhaps suggestive of the Kinderhook, as resistant layers of chert are a constant feature of that formation where it is exposed in Marshall county.

Mississippian Series.

Representatives of the Lower Carboniferous or Mississippian series, of the Carboniferous system are nowhere exposed in the county. In Marshall county to the north exposures of the Kinderhook strata are found along Timber creek near Ferguson, between five and six miles from the Jasper county line. The Coal Measures in Marshall county rest upon the Kinderhook beds; strata belonging to the Saint Louis stage being in general absent. As has been noted earlier, the Saint Louis limestone is recognized in the Grinnell deep well section. Mr. A. J. Jones* assigns to it a thickness of fifty-eight feet, and refers underlying argillaceous beds to the Augusta stage. Professor Norton, in his report on the Artesian Wells of Iowa, notes that the Saint Louis limestone is present, but does not separate this stage from the preceding one. The limestone in which the first flow of water is obtained at Newton is referred by Professor Norton† to the Saint Louis. This authority also expresses the probability that the source of supply in the Colfax wells is in the same formation.

The strata of the Saint Louis stage are typically exposed in Mahaska and Marion counties. In the latter a thickness of 270 feet of Mississippian rocks above the Kinderhook was penetrated in the deep well at Pella. At Mitchellville, in Polk county, Bain‡ has with some doubt referred forty feet of strata to the Saint Louis stage; while to the westward the formation rapidly thickens as the records of the Greenwood Park well and other deep drillings in and near Des Moines go to show.

*Iowa Acad. Sci., Vol. II, p. 82, 1894.
†Artesian Wells of Iowa. Iowa Geol. Surv., Vol. VI, p. 292.
‡Ann. Rep. Iowa Geol. Surv., Vol. VII, p. 291.

Taking a somewhat broader survey of the relations between the Coal Measures, the Saint Louis strata and the underlying rocks, it is found that, at no place in the counties to the southeast, along the strike of these strata, where the geology has been studied in detail, has the absence of the Saint Louis limestone been observed. To the northwest across Marshall and Hardin counties the rocks of the Des Moines stage rest upon beds older than the Saint Louis. In Webster and Humboldt counties the Saint Louis limestone is again recognized. It is thus seen that over the area mentioned the materials composing the Saint Louis strata were either never deposited, or were worn away before the Coal Measures were laid down. The first assumption seems probable in view of the fact that where observed in the Grinnell and Mitchellville wells these strata are thin in comparision with the corresponding strata farther south and west. A gradual thinning or wedging of the Saint Louis deposits is indicated, and beyond its limits the Des Moines strata overlap, and rest upon the older formations.

In Jasper county the area underlain by the Kinderhook rocks can not be definitely outlined as these materials are deeply buried beneath the glacial deposits; nor are any strata referable to the Augusta known. The area outlined as Kinderhook on the map is determined by projecting the line of the strike from outcrops in Marshall county. Neither can the border of the Saint Louis deposits be traced. It is not believed to be the country rock in any part of the county, but the interest that attaches to it comes from its wedging out and giving way to the Kinderhook as the floor upon which the Coal Measures rest. The line of overlap apparently has a northwest-southeasterly course, and can not lie far within the limits of the Coal Measures themselves.

the river but sixteen to eighteen feet are in view. The nature of the sandstone is such as to leave no doubt of its equivalence with the beds on Elk creek near Murphy. The concretionary iron nodules are more common here, being frequently of considerable size, and partly filled with argillaceous material. The dense, siliceous bands are quite conspicuous, assuming often the appearance and properties of a partially hydrated hematite iron ore. They mark the lines of contact between heavy beds, and attain a thickness of several inches.

The quarry openings along Rock creek, in section 17 of Rock Creek township, are the most northerly exposures of this formation in the county. At the old Morgan quarry in the northwest ¼ of the same section the following strata may be seen:

		FEET.	INCHES.
5.	Kansan bowlder clay	8	
4.	Weathered, brown sandstone	1	6
3.	Ledge of buff sandstone	6	
2.	Shattered and cross-bedded sandstone	2	
1.	Reddish-brown sandstone in a heavy bed	4	

Prospecting in the neighborhood indicates the presence of the sandstone as far north as the edge of this section, and towards the northeast into section 8. The rock has been quarried near the middle of section 17 where the wagon road crosses Rock creek. In the northeast ¼ of the northwest ¼ of section 9, along a branch of Rock creek, a spring line appears to represent the base of the sandstone. A few feet only of crumbled sandstone are to be seen in place, but the evidence here, and in section 6 to the south, goes to indicate that this formation is very thin. No further trace of it is to be found towards the northeast.

The Red Rock sandstone appears to occupy a narrow, elongated depression in the Coal Measure strata. In general it stands higher than the Coal Measures outcropping on either side of it, but this may be accounted for by its more resistant character. It lies unconformably upon the Coal Measures and, at two points where it has been penetrated, the Coal Measure strata lie beneath it. At the Herwehe quarry west of Reasnor,

The latter frequently consist of concentric, ferruginous shells between which sandstone is intercalated. The greatest thickness of beds is found in the old Dooley quarry, where the ferruginous bands appear as firm crusts of siliceous limonite, separating the major beds of the section. The rock is coarse in texture, friable, and varies in color from gray to deep red. All the layers seem to be thoroughly impregnated with iron oxide.

FIG. 26. Exposure of weathered, brown sandstone of the Red Rock formation, in section 30 Rock Creek township.

The Red Rock sandstone outcrops on both sides of the North Skunk river east of Kellogg. In the western part of section 30, Rock Creek township, a quarry face some six to eight hundred feet in length has been opened along a small creek. See figure 26. In the northeast ¼ of section 25, Kellogg township, the sandstone may be seen in the old railroad quarry. In the southeast ¼ of the same section along a small creek entering from the south, heavy ledges of the same strata are exposed. The maximum thickness here is twenty-five feet, while along the north side of

stratified sand and gravel from the drift materials. First beneath the drift, is a two-foot seam of coal. Beneath this are fire clay, shales and sandstones, thirty to thirty-five feet. A lower vein of coal, varying from fourteen inches to four feet in thickness, occurs near the water level and it is usually overlain by a thin band of sandstone. Large masses of calcareous clay-ironstone occur in connection with the coal seam. A carbonaceous shale lies above this sandstone roof, then a band of white sandstone which grades into sandy shales above. The complete section at this point involves some forty feet of Coal Measure strata.

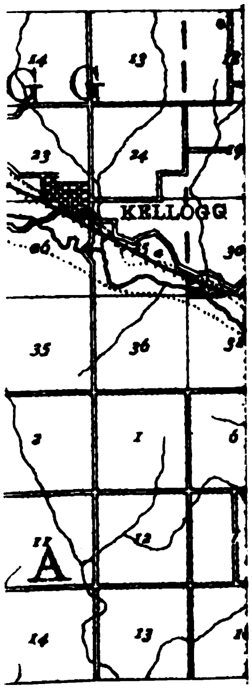
In the northwest ¼ of section 4 of Mound Prairie township, west of the wagon bridge, the Skunk river flows at the foot of an exposure which shows in general the following sequence. The various layers change rapidly, both in character and thickness, when followed along the outcrop. The measurements given were made near the east end of the exposure.

		FEET.	INCHES.
6.	Sandy loess	15 to 18	
5.	Sandy clay-shale, grading into laminated sandstone	17	
4.	Sandstone	4	6
3.	Carbonaceous shale, coaly	1	
2.	Fire clay, with iron concretions	2	
1.	Arenaceous clay-shale, and talus, to water	6 to 8	

A shaft at the "Klondike" coal mine in the northeast ¼ of section 20, Mound Prairie township, was sunk through the following strata:

		FEET.	INCHES
8.	Clay, free from gravel	15	
7.	Black slate	5	
6.	Coal		8
5.	"Fire clay," including eight inches of sandstone	13	
4.	Flint rock ("cap rock")		10
3.	Black slate	35	
2.	"Corduroy" slate (white with streaks of limestone)	20	6
1.	Coal	4	8

The following is the section of a well put down on the farm of A. W. McDonald, in the southwest ¼ of section 8, Washington township:


KELLOGG

About five feet below the bottom of the bank is a ten-inch seam of coal. This crops out in a ravine a short distance below the plant. Beneath this coal the fire clay has been penetrated to a depth of twenty-five feet. The well at this plant is 197 feet in depth. No coal appeared in the well section, the lower ninety-seven feet being reported as through sandstone.

In sinking a shaft at the Wm. White mine in section 22, Des Moines township, the following strata were penetrated. The shaft is located on the slope at the west edge of the valley of Walnut creek.

		FEET.	INCHES.
6.	Gravelly surface clay	15	
5.	Sandstone		4
4.	Sandy fire clay	14	3
3.	"Cap rock" (limestone)	1	6
2.	Slate, jointed	2	
1.	Coal	4	

The foregoing sections will emphasize the variability of the Coal Measure strata. The localities in which exposures are most abundant represent areas of thin drift covering. In such areas the coal-bearing strata lie close to the surface, and in these regions the most of the coal mining has been done. The coal beds of the county that have been explored appear to exist in separate and isolated basins of limited extent. The lack of persistence of individual strata in general makes it impossible to accomplish much in the way of correlation between separated localities.

RED ROCK SANDSTONE.

This formation is included in the Des Moines stage of the Upper Carboniferous series, but it may be differentiated from the Coal Measures proper because of its uniformity, and the somewhat unique relation which it appears to bear to the other members of the series. In Jasper county it occupies a narrow, elongated area coextensive in direction and width with the territory covered by it in Marion county. While its boundaries could not be accurately traced, its probable limits have been mapped by a study of outcrops and well sections. The general trend is northeast-southwest, and in width it averages two and

one-half to three miles, tapering to the northward. No evidence of it was found beyond the exposures along Rock creek and its branches in sections 9 and 16 of Rock Creek township.

Outcrops of this rock are to be seen at various points near Reasnor, on both sides of the Skunk river; along Buck creek; on Elk creek near Murphy; along North Skunk river in the vicinity of Kellogg, and on Rock creek as noted above.

Mr. B. L. Miller * has briefly described the quarry exposure in the northwest ¼ of section 8, Fairview township, as follows:

		FEET.
4.	Soil	1
3.	Weathered, brown sandstone	9
2.	Heavy beds, yellow-grey, variegated	10
1.	Dark red sandstone, heavy bedded	8

Two small quarries are opened here and both the brown and the red stone have been taken out. Cross-bedding is very conspicuous in the upper part of the section. The change in color is gradual from the top downwards, and appears to be due to the degree of leaching and hydration which the rock has undergone. Chemical tests of the brown sandstone show a loss on ignition of 3.8 per cent, and 16.27 per cent of iron and alumina oxides. The dark variety pulverizes to a deep red and ocherous powder, and analyzes 31.5 per cent Fe_2O_3. At one point in section 21 of Fairview township a weathered outcrop of the red stone occurs from which the resulting ocherous iron oxide has been taken for mineral paint. In places in both the red and the brown sandstone bands or nodules of a dense, flinty character occur, which appear to be quartzitic in nature and origin.

The outcrop of this rock is practically continuous along the west border of the Skunk river valley from the exposure just described to those along Buck creek near Monroe. The hills bounding the valley are all supported by the sandstone, and where the river flows close to the west edge of its valley, west of Reasnor, the brown sandstone appears as a continuous ledge for some distance in section 10 of Palo Alto, and section 9 of Fairview townships. In the road across the south part of section 29, Fairview township, the sandstone is exposed on both

*Geology of Marion County, Ann. Rep. Iowa Geol. Surv., Vol. XI, p. 159, 1900.

sides of small stream near the center of the section, east and west. The drift covering is thin here and the rock is weathered into a friable sand which can be removed with the shovel. The sandstone outcrops again at the point of a prominent hill known as "Stony Point" in section 14, Elk Creek township, where the river flows near the east side of its valley. A thickness of about forty feet of heavy beds is exposed, having the usual texture and brown to gray color. Although quarrying has been done here, the section is much obscured and the red sandstone can not be seen in place. However, the presence of loose fragments, indicate that the dark red variety is present above the water level of the river. Fairly well preserved fragments of Calamite stems are to be found in the talus from the weathered top strata.

On the hill slope a short distance north of the town of Reasnor, fourteen feet of the sandstone may be observed in a small quarry; the prevailing color is brown, approaching a red, in places. The sand grains are at times so coarse and irregular in size as to give the rock a finely conglomeratic texture. Many of the largest grains are of a jaspery nature, and some, approaching a pebble in size, appear to be fragments of an earlier sandstone. Cross bedding is not uncommon. The base of this exposure is about sixty feet above the flood plain. In detail, this section is as follows:

		FEET.	INCHES.
7.	Loess, becoming fine sand on the hill-top...	4	
6.	Buff sandstone, micaceous		6
5.	Brown sandstone, cross-bedded.............	2	
4.	Heavy-bedded sandstone, conglomeratic	2	6
3.	Laminated, red and grey sandstone, cross-bedded....................................	1	6
2.	Heavy bed of brown sandstone, containing ferruginous, sometimes hollow, nodules.....	4	6
1.	Like No. 2 to base of quarry..........	3	

In the northwest ¼ of section 21, Buena Vista township, on Elk creek, there is exposed in two small quarries a maximum thickness of twenty-two feet of the sandstone. It exhibits the same characters as in former sections as to bedding and color. Some of the red is to be seen but the brown variety prevails. In the Lanphear quarry the jaspery, quartzitic bands are quite pronounced, as are also the spheroidal nodules.

The latter frequently consist of concentric, ferruginous shells between which sandstone is intercalated. The greatest thickness of beds is found in the old Dooley quarry, where the ferruginous bands appear as firm crusts of siliceous limonite, separating the major beds of the section. The rock is coarse in texture, friable, and varies in color from gray to deep red. All the layers seem to be thoroughly impregnated with iron oxide.

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Exposures of any considerable importance are rare. At occasional points along North Skunk the river has gouged out its valley walls, and sections of some interest may be observed. Near the southeast corner of section 5, Richland township, at the west bank of the river, is an outcrop thirty-seven feet in thickness of modified Kansan drift, capped with thirteen feet of loess. The drift is very sandy, the sand being mostly in pockets, although it is in part stratified. The whole section is brown and iron-stained and certain bands are quite firmly cemented with iron oxide.

In the southwest ¼ of section 8, Kellogg township, and southward into section 17, the river is skirted on the south by high bluffs of Kansan till and loess. In these bluffs exposures, sixty to seventy feet in thickness, of blue and oxidized till are seen, capped with twenty feet or more of loess. The bluffs rise immediately from the river and form a conspicuously abrupt topographic feature. Farther up the North Skunk river, in section 1 of Newton township, near the middle of the north side of the section, about forty-three feet of typical Kansan drift are exposed. The lower twenty-two feet are oxidized, blue bowlder clay.

Railroad cuts furnish occasional instructive drift sections. Figure 28 is from a photograph showing a hill of Kansan drift, covered with loess. At the contact of the loess and drift there is frequently found a band of iron-stained bowlders which conforms to the contour of the drift surface. These are large and small, but all above the sand grain in size. The ferretto is always conspicuously evident, which indicates a long period of weathering prior to the loess. If it is granted that winds have been instrumental in loess deposition, the bowlder bands may represent the heavier portions of the till which neither the wind nor rain erosion could easily remove; considering loess deposition to have been well under way while the drift surface was still largely unprotected by vegetation.

The number of classes of rocks represented in the bowlders of the Kansan drift is surprising. And yet when one reflects that some have been transported from even the more remote regions of Canada, there is little cause for surprise. A list of

the varieties picked from one exposure, not more than fifteen feet in vertical extent, includes the following which were recognized with the naked eye: chalcedonic quartz, white glassy quartz, jaspery flint, quartz porphyry, fine-grained gray granite, fine-grained pink granite, coarse-grained pink and gray granites, dark gray hornblendic gneiss, white, red and

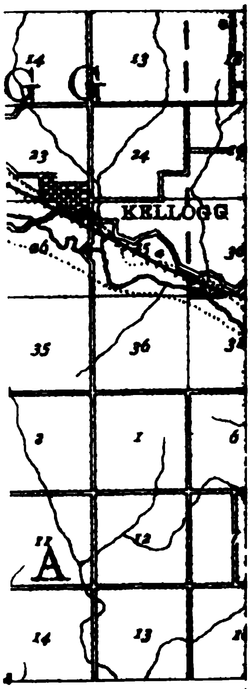
FIG. 28. Loess overlying Kansan drift, in cut along the Newton and Northwestern railway section 5 of Palo Alto township.

pink quartzites, weathered limestone, gray sandstone, clay ironstone and septarian nodules with calcite veining. Aside from those listed, at least a dozen varieties of the darker colored, more basic, igneous rocks were collected which would require microscopic examination for even an approximate classification.

In Marion county the Red Rock sandstone is known to rest directly upon the Saint Louis beds at a point near Elk Cliff. Elsewhere in this county, and wherever observed in Jasper county, Coal Measure shales underlie the sandstone. The thickness of this formation in Marion county is estimated at 100 feet. So far as can be ascertained, its thickness in Jasper county ranges from more than sixty feet as a maximum, near Monroe, to nothing in Rock Creek township where it disappears. The area occupied by it is tongue-shaped tapering to the north.

Mr. B. L. Miller* suggests contemporaneous erosion as the best explanation for the peculiar occurrence of this sandstone. It undoubtedly occupies a valley in the Coal Measure strata, and contemporaneous excavation appears adequately to account for such a depression. Some clue as to the direction from which the sand was brought in during deposition may perhaps be obtained by a study of the cross-bedding which is conspicuous in nearly every exposure. This structure is often clearly brought out by the presence of alternating laminæ of brown or dark red, and buff to light yellow sands. While the dip and the strike of the cross beds were not found to be constant in any two exposures, nor in any two beds in the same exposure, it was observed that the strike was prevailingly to the south of east and in a number of instances, where it could be accurately measured, proved to be at essentially right angles to the northeast-southwest direction of the depression which the sandstone fills. This is, of course, not corroborative evidence as to the origin of the depression itself but rather points to the fact only that much of the deposit was put down by water moving in a definite and constant direction; and the attitude of the bedding planes suggest as the agent a current of water flowing through this ancient valley.

*Geology of Marion County. Iowa Geol. Surv., Vol. XI, p. 154, 1901.



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Pleistocene System.

Glacial deposits cover essentially the whole of Jasper county. Materials representing three ice invasions are present. They consist in large part of bowlder clays associated with gravels, sands and silts that have been partially reassorted by the erosive agents. As mentioned under Topography, the surface features of the county are in general due to the ice deposits. The maximum recorded thickness of the drift is 320 feet.

At some points beds of gravel and sand are found at the base of the Kansan drift. In fact, it is quite the usual thing for well drillers to report such beds immediately overlying the shales of the Coal Measures. It is possible that these may indicate an earlier or pre-Kansan drift. No exposures were observed, however, nor were accurate well data secured showing the presence of an earlier drift. The gravel beds could have been derived from the Kansan during its deposition.

Deposits referable to the Pleistocene system are, therefore, the Kansan drift, a possible thin veneer of Iowan, the loess, Wisconsin drift and post-glacial materials.

KANSAN STAGE.

Jasper county is included in the area covered by the Kansan glacier which extended southward far beyond the borders of the state, into Missouri and Kansas. The materials left by this sheet of ice comprise in general a heavy deposit of heterogeneous bowlder clay that mantles the whole county. The character of the drift is not constant. In places it becomes very gravelly and by its partial stratification shows the effect of running water in its deposition. Pockets and lenses of sand are not infrequent in the bowlder clay. The Kansan varies a great deal in thickness according to irregularities of the old land surface on which it was spread. It is not uncommon to find well sections in which a thickness of 200 feet of material referable to the Kansan has been penetrated. Notable areas where the drift is unusually thick are northern Newton township and in much of the northern part of the county.

Exposures of any considerable importance are rare. At occasional points along North Skunk the river has gouged out its valley walls, and sections of some interest may be observed. Near the southeast corner of section 5, Richland township, at the west bank of the river, is an outcrop thirty-seven feet in thickness of modified Kansan drift, capped with thirteen feet of loess. The drift is very sandy, the sand being mostly in pockets, although it is in part stratified. The whole section is brown and iron-stained and certain bands are quite firmly cemented with iron oxide.

In the southwest ¼ of section 8, Kellogg township, and southward into section 17, the river is skirted on the south by high bluffs of Kansan till and loess. In these bluffs exposures, sixty to seventy feet in thickness, of blue and oxidized till are seen, capped with twenty feet or more of loess. The bluffs rise immediately from the river and form a conspicuously abrupt topographic feature. Farther up the North Skunk river, in section 1 of Newton township, near the middle of the north side of the section, about forty-three feet of typical Kansan drift are exposed. The lower twenty-two feet are oxidized, blue bowlder clay.

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IOWAN STAGE.

The observed facts concerning the Iowan drift in this county have been fully stated under Topography. No deposits of characteristic bowlder clay attributable to this ice sheet were found. Occasional large, fresh granite bowlders and the general monotonous, level surface constitute the basis for the inference that the Iowan ice probably spread over the northeast corner of the county.

LOESS.

The loess of this area exhibits the usual characteristics of that deposit. It is a fine-grained, silty material, which forms a continuous surface covering over the whole county outside of the area of Wisconsin drift. It is universally pebbleless with the exception of the lime carbonate concretions which in places are very abundant. The loess frequently grades downward into more sandy varieties, and even into fine sand, at times, which appears to be continuous with the body of the deposit. It varies in thickness from a scarcely recognizable veneer to a thickness of more than twenty-five feet. Although usually structureless, a banding is frequently noticeable, but the bands are not persistent or uniformly horizontal, and will not be mistaken for the characteristic stratification of strictly water-laid sediments.

As has been noticed in other portions of the state, the loess appears to bear a genetic relationship to the Iowan drift. Skirting the edge of this drift sheet, the loess hills are generally conspicuous and from this belt the loess is spread over all earlier formations to the southward beyond the boundary of the state. In Marshall and Tama counties loess overlies the Iowan drift near the border of this drift sheet.

It is found, further, that the loess materials are in general coarser near the Iowan border and grade into finer and finer silts as its distance increases. This rule will scarcely hold where, as in many instances, the loess bordering river valleys can be seen to have come partly from the flood plain itself.

There are certain features of the loess and its relation to associated deposits that may be mentioned. It was possible in a

few instances to view sections showing loess covering irregularities in the Kansan drift surface. As a general rule the topography of the underlying Kansan is preserved in the loess features of today. The thickest loess rests on the tops of the hills, but the capping of loess does not always cover symmetrically the earlier contours. Occasional road cuts, the best examples of which were observed along Rock creek in Hickory Grove township, show the greater thickness of loess on one flank of the old Kansan hills to such an extent that the highest points of the present surface come above the flanks, rather than over the old hilltops. Materials deposited by winds are heaped up largely on the opposite side of an obstruction from which the wind blows. Could a sufficient number of sections be studied, they might afford a definite clue as to the direction of the prevailing winds during loess deposition.

Another possible clue to the wind direction may be had from the fact that the thickest accumulations are found along the east and south borders of the river valleys. This distribution suggests northwest winds, and the great thickness of the deposits suggests a readily available source of supply. The broad, open flood plains of the rivers may themselves have afforded material transportable by winds. Dr. Beyer*, in his report on Story county, has pointed out that such accumulation is in places going on at the present time. This process can be observed at several points along the Skunk river where sands are shifting to such an extent that considerable areas are made barren of vegetation. The deposition of considerable quantities of material similar to that which makes up the mass of the loess is not, however, believed to be going on in this county at present.

Shells of land mollusks are found in the loess at various points. No effort was made to collect a complete series of the fossils in the loess. Prof. T. E. Savage has identified the following: *Succinia avara* Say, *Succinia ovata* Say, *Polygyra multilineata* Say, *Pyramidula striatella* Anth. The fossils were most abundant in the heavy deposits occurring along the principal waterways. In fact, few, if any, were seen in upland localities.

*Ann. Rep. Iowa Geol. Surv., Vol. IX, p. 218, 1898.

The best sections of the loess are to be observed in road cuts along the major streams. Figure 29 is a typical exposure at the southeast corner of section 20, Elk Creek township. Molluscan remains and calcium carbonate concretions are abundant in this exposure. Excellent sections are also to be observed along the Chicago, Rock Island and Pacific railway east of Colfax. Where the railroad leaves the flood plain of the Skunk river, in

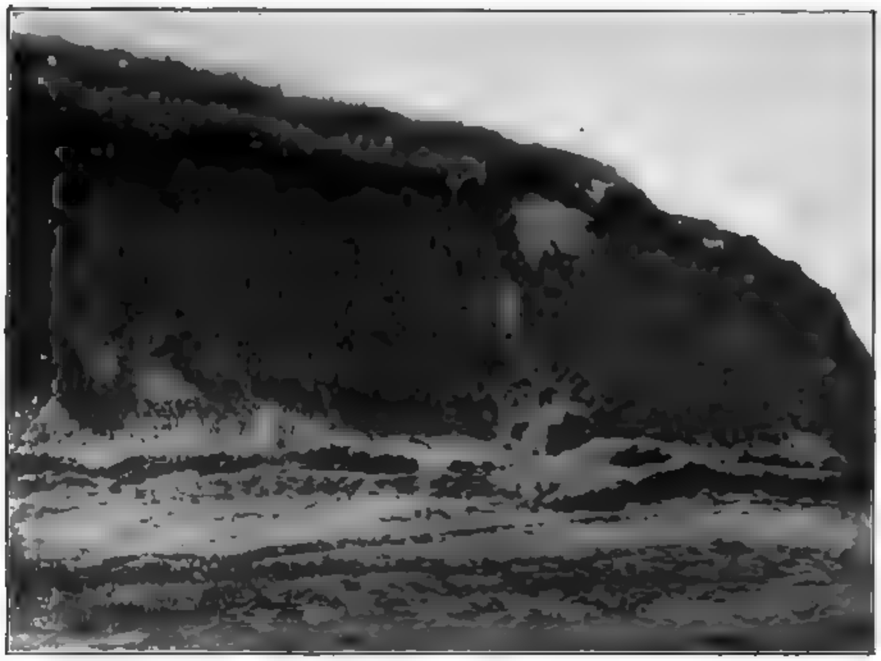


FIG. 29. Loess bluff twenty-five feet in height, containing numerous land shells and lime concretions. Near the southeast corner of section 20, Elk Creek township.

section 6, Mound Prairie township, a hill is dissected, exposing to view a thickness of twenty-five to thirty feet of lòess. Fossils are especially abundant in all portions of the section.

Loess buried beneath the Wisconsin is to be seen at a few points near the border of this drift sheet. Such loess is in general of a bluish color, streaked with iron oxide. A typical exposure of this nature was observed near the northeast corner of section 7, Clear Creek township, in the valley of Silver

creek. Here, some 300 yards below the east and west road, fifteen feet of loess were seen beneath twelve feet of Wisconsin drift. The upper portion of the loess is filled with root casts of iron oxide, and seams of iron stains traverse it irregularly. The casts are hollow, with occasional exceptions where decayed organic matter is still in them, and are frequently from one to one and one-half inches in diameter. These features both disappear with depth, and the lower part of the section is clear steel-blue in color.

A similar phase of the loess was found on the farm of Mr. Andrew Engle, one-half mile north of Metz. Along a gully leading into the valley of the Skunk river a few feet of steel-blue clay, overlain by a foot or two of deep red clay, are to be seen, both covered with six to eight feet of soil wash from the neighboring hillsides. The blue clay has very fine and sharp grains. It has been utilized to a limited extent as a polishing agent for domestic purposes, and besides it possesses decidedly saponaceous properties.

WISCONSIN STAGE.

The Wisconsin ice deposited drift over a small area in the northwest corner of the county. The earlier topographic features were obliterated by the Wisconsin glacier, in part by the distinctive material that it deposited. Owing to its comparatively recent date, leaching and oxidation of this drift sheet have not progressed to the advanced stage represented in the Kansan till. It is to be remarked, too, that there is quite a marked difference in the degree of freshness between the Wisconsin till, as exposed in Jasper county, and the same drift in portions of Story and other counties to the north. The deposits in this area mark an early advance of the Wisconsin lobe.

The drift is composed of a promiscuous mixture of clay, rock flour, bowlders of all sizes and many varieties. While in the Kansan the more basic igneous rocks were the predominant types, in this later drift the granites and light colored varieties prevail. The drift has been locally modified by the action of water but in general it still retains the characteristic properties of glacial deposits. North of Indian creek, in the southern part

of Clear Creek township, the hills are of morainal character. They are knobby and the materials composing them are very gravelly. This may be observed in the roads crossing them and is quite apparent in some places by the scantiness of the vegetation. With this exception, the Wisconsin is a thin sheet of typical glacial till which is much attenuated at its borders. The flow of water during the melting of the ice appears not to have been great for the common extra-morainal features, gravel terraces and trains, are practically absent.

The thickness of the Wisconsin drift is not great. It is seldom possible to obtain reliable data from the wells in the area, but where exposed along stream-ways thirty-five feet is about the maximum thickness. On Silver creek, in section 7, Clear Creek township, exposures are to be seen. The upper fifteen to eighteen feet are oxidized to a buff or yellowish hue while below, the original blue color is preserved. It is very calcareous, effervescing freely with acid in all parts of the section. Good exposures are also to be seen along Wolf creek, at Valeria, and along an unnamed tributary of the Skunk river, previously mentioned, in sections 8 and 9 of Washington township.

POST-GLACIAL SANDS, SILTS AND ALLUVIUM.

Attention has already been directed to the occurrence of mixed sandy and silty deposits, especially bordering the Skunk river valley. The deposits appear typically as hills, in greatest number along the eastern side of the valley. In the region of Colfax, where the river has an east and west direction, abundant materials of this nature are found on the upland back from the river.

In Poweshiek township, over the Wisconsin drift area, similar materials skirt the flood plain and cover the hills to a distance of from one to three miles from the stream. The deposit here very much resembles the loess. There are no fossils, however, and the material is more sandy and works up in the road beds to depths of six or eight inches. In this region the source is undoubtedly the broad flood plain of the river, and the movement of the materials is still in progress. The de-

posit here is continuous with that outside of the Wisconsin area which covers, to a considerable depth in places, the adjacent uplands in the vicinity of Oswalt. Difficulty was found in accurately tracing the boundary of the newer drift in southern Poweshiek township because of the heavy mantle of this recent deposit.

In this portion of the county, as also in the region of Colfax, these deposits closely resemble the loess, in fact, it is impossible to make out clearly the exact relation of the two. In the town of Colfax, typical loess is used for brick making, while south of the town what appears to be a continuation of the loess is a very sandy silt which possesses little plasticity and is so loose in texture that vegetation can with difficulty gain a foothold.

At Goddard station, in Sherman township, a sandy phase of the loess is being removed by the railroad from the base of a hill bordering the Indian valley. Up the hillslope it grades into loess which overlies Kansan till. Similar materials are found at intervals southward along the east side of Skunk river. They are also conspicuous on the hills above Reasnor, and they continue in importance southward to the boundary of the county. In section 13, Elk Creek township, low sand ridges extend into the valley. These are also to be seen in section 29. In section 33 all of the hills are very sandy. Near the north border of this section a small stream has exposed a thickness of twenty feet of finely stratified and nicely sorted sand. The laminæ are horizontal, the sand being white, yellow, brown and red. The grains are rounded and uniform in size. Covering the sand, and separated from it by a perceptible dividing line, are eight feet of sandy loess. The sand is a purely water-laid deposit and bears no genetic relationship to the capping loess.

It is to be remarked that wherever the sands are exposed outside of the area of Wisconsin drift, they are covered with a layer of greater or less thickness of loess-like, silty material. It may be noted further that the sand deposits occur in two positions; as low ridges at the border of the flood plain, in which the sand is comparatively coarse; and along the upland sides of the bluffs which immediately bound the valley, where the

material approaches in nature what might be termed a sandy loess. These bluffs are in general prominent, and they are composed of loess containing fossils, and which retains the characteristically high angle of slope.

Mr. B. L. Miller* calls attention to the occurrence of sand ridges in Marion county. One such ridge mapped by him in the northeast corner of Marion county is similar in every respect to the deposits just described. The formation of the ridges is attributed by Mr. Miller to the action of southwest winds, "all of them being northeast of the place where the sandstone ledges have been cut through." The Skunk river cuts through the belt of Red Rock sandstone in the south-central part of Jasper county, but the relation between this region and the greatest development of the sand ridges specified by Mr. Miller does not obtain here. Nor do the sands themselves suggest such an origin. The Red Rock sands are prevailingly of a deep red or brown color; while the sand hill deposits are of the lighter shades, much of them white.

There seems little doubt that the wide flood plain has furnished much of these sands and silty products which the sweeping winds have caught up and deposited where they are now found. Evidence points to northwest winds. The fact that there is universally a surface layer of loess is suggestive as to the time of accumulation.

All of the streams of any considerable size flow through alluvial valleys. In the valleys of the major streams the alluvium has accumulated to great depths. It is a stratified deposit put down and distributed largely by the rivers themselves. Strata of sand and occasionally gravel occur, interbedded with the finer river silt.

At a few points, remnants of stream terraces are found. They are generally covered with alluvium and sometimes by the loess. At Valeria there is a flat bench of Wisconsin drift some twenty-five or thirty feet above the present Skunk river flood plain which is surfaced with a thin layer of river silt and extends from the west county line to a point some three-

*Iowa Geol. Surv., Ann. Rep. Vol. XI, p. 167, 1900.

quarters of a mile below the town. This appears to be a remnant of the old flood plain of the river, and represents a definite stage or halt in the down cutting of the stream.

Suggestions of former terraces are to be seen at intervals along the North Skunk river. Below the schoolhouse in the southeast corner of section 16, Malaka township, there is a narrow terrace ten to twelve feet above the water, and capped with loess. Low, alluvial terraces bound Indian creek to the west in sections 28 and 33 of Clear Creek township. Below Mingo they again occur. In section 10 of Clear Creek township, Wolf creek is skirted on the west by a drift terrace. This is seen again in the southwest ¼ of section 17 of the same township.

Soils.

The soils of Jasper county may be grouped into three fairly distinct types, drift soils, loess soils and alluvium. The materials of the glacial deposits are practically the sole source of all three varieties, but each represents a modification of the original till.

Soils belonging to the drift proper cover but a small proportion of the county. Outside of the Wisconsin drift area they are not important. On some of the steeper slopes in the loess-Kansan area, the Kansan drift outcrops near the base of the hills and contributes in some measure to the soil forming elements. This is evident in some places by the oxidized color and bowldery nature of the soil, and in others by the wet or spring line at the contact with the overlying loess. While it is rare that any effect on the vegetation or crops can be seen, nevertheless, cases are not lacking where quite distinct zones can be distinguished from the hilltop down the slope. These plant zones are determined by the zones of loess, Kansan drift, and wash or loam soils; the more luxuriant growths being on the lower portion of the slopes. The contained gravel and bowlders are not favorable to tillage.

The Wisconsin drift is covered with a soil, whose unoxidized character and moderate depth attest its newness. It is usually

of a yellowish-brown color where undisturbed, and it is not yet leached of its lime, which is present even close to the surface. Its color is in contrast to the deep red of the old Kansan soils. Drainage is not perfect so that as yet the productiveness of this new drift soil does not rival that of the loess and alluvium. Artificial drainage would improve it and permit the weathering agents to act more effectively.

The loess soils occupy much the larger portion of the area of the county. They form a porous, open-textured stratum through which water readily percolates. The loess is, however, prevailingly calcareous, and does not exhibit an advanced state of oxidation. Its loose texture causes it to erode rapidly on steep slopes where it is exposed without a covering of vegetation. The loess is typically of fine grain, but as has been pointed out, becomes decidedly arenaceous, and even grades into fine sand in certain localities in Jasper county. Chemically it is not widely different from ordinary clay, the presence of the alkalies and alkaline earths showing it to be made up of a variety of mineral substances. These minerals, in weathering, furnish a variety of elements for plant growth. The loess soils are of reputed fertility, and, especially where slopes are moderate, produce abundant crops of the leading cereals.

Many of the streams of the county are bordered by belts of alluvium. This material affords a very fertile soil, being made up of the loose fragments of soil, clay and humus that have been carried into, and distributed by the streams, over their flood plains. It is of a prevailingly dark color and is commonly underlain by strata of sand which afford it good drainage. The alluvial soils are eminently rich. On account of their position, spring cultivation is sometimes retarded somewhat, and such areas are subject to occasional inundation. These drawbacks are not usually serious, for the soil is warm, and in the river valleys some of the best crops in the region are grown.

The soil materials as they are loosened and weathered tend to accumulate on the lower slopes of the hills and, if at the border of a flood plain, to spread out in the shape of the alluvial fan. Such deposits show little, if any, stratification and, as they occur along all depressions and small streams, they con-

stitute an intermediate type of soil between the upland and the alluvium. To them the term loam has been applied. They are similar in composition and texture to the alluvium but are not so far removed from their original source. The loams constitute a very productive soil.

ECONOMIC PRODUCTS.

Coal.

The coal deposits of Jasper county have been exploited since the early 50's when the Slaughter bank was opened in section 32 of Sherman township. Coal was also mined along Cherry creek in Newton township at an early date. Whitney* stated in 1858 that considerable coal had been mined at both of these localities. Owen,‡ in 1851, mentioned the use of coal for blacksmith purposes from a "three-foot seam in Jasper county, near the Skunk river."

The first Biennial Report of the Iowa State Mine inspector,† in 1883, contains the following estimate:

"A majority of the superficial area of this county is barren of coal; the most of the coal lies in the southwest portion of the county, on North Skunk river and its tributaries, and the tributaries of the Des Moines river, but not more than the superficial area of one township is underlaid with coal of workable thickness."

Later exploitation has proved the extreme conservatism of these statements.

The number of producers did not increase rapidly until in the '80's, when, in 1885, there were twenty mines in operation. There are at present sixteen mines in the county which operate a portion or all of the year. The largest production for one year, for which statistics are to be had, is 293,255 tons, produced in 1892. From this the tonnage decreased to scarcely more than 100,000 in 1900, but the output is again increasing, so that 1904 has a reported production of nearly 275,000 tons.

* Rep. Geol. Surv., State of Iowa, Vol. I, pt. 1, p. 296, *et seq.* 1858.

† First Biennial Report State Mine Inspector, p. 23, 1883.

‡ Geol. Surv. Wisconsin, Iowa and Minnesota. p. 117. 1851.

The various sections of the county where productive coal beds have been worked will be designated by the nearest towns, and the occurrence of the coal and the mines in each district will be briefly described.

Lynnville district.—On the east side of north Skunk river, two miles north of Lynnville, coal has been taken out but no active mining work has been carried on for several years. There are three veins, an upper, two to four feet in thickness, a second, twenty-two inches, and a lower vein about sixty-five feet below the top one, eighteen inches in thickness. The top seam only has been worked. One shaft was sunk, but the coal was removed mostly through drifts. The coal is covered with fifteen to twenty feet of glacial clay and light blue shale, the latter affording a fairly good roof. The workable seam is about twenty-five feet above the river flood plain. Coal has been taken from it at a number of points southward along its outcrop. The coal mined here is said to have been of good quality, being especially low in sulphur.

On the west side of the North Skunk river, near the middle of section 3, Lynn Grove township, a coal seam outcrops in the bed of a small creek from the southwest. Prospecting has been done along this stream. There appears to be two veins, one near the water level, and the second seventeen feet higher up. As far as could be learned no coal has been mined here.

Along Rafferty creek, in sections 33 and 34, Richland township, coal mining began at the Meredith bank in 1860. This bank has not been operated for eighteen years. Two seams are reported, an upper, two feet and four inches in thickness at about the water level; and a lower, thicker vein that has not been exploited. Borings for wells close to the North Skunk river encounter the coal just beneath the drift, but back from the flood plain to the west, shales are interposed over the coal.

Coal has been mined in this district only along the streams where the outcropping beds have been easy of access. It is scarcely probable that workable coal would be found east of the old mines first described. The general dip being to the west, the southwest portion of Richland and the northwest

part of Lynn Grove townships appear to be more promising areas for prospecting.

Monroe district.—It is impossible with the few deep borings and meager records available to ascertain the extent of the coal basins in this district. In limited areas where correlation is possible the veins are found to be irregular, so that no attempt is made to check from one district to another.

In Fairview township a group of mines is located three or four miles east of Monroe. When first opened, a flourishing camp by the name of Draper sprang up, and in 1887 there were seven mines operating intermittently in this vicinity. The Jasper County Coal and Mining Company operated extensively here from 1887 to early in the '90's. Since that time there have been on an average three mines in operation supplying a small local demand.

There are two coal seams, an upper, running three and one-half to four feet in thickness, and a lower vein usually four feet or more in thickness. The early mines worked the thicker bed, but at present mining is done only in the top seam. The two beds are separated by from thirteen to thirty-five feet of shale and sandstone.

The Marshall slope is located near the center of section 33 and has been operated for twenty-five years. The upper seam, averaging three and one-half feet in thickness, is mined. It here has a dip to the north of one foot in twelve. Eighteen feet below is the second vein of four feet. It is a "shooting" coal and is not mined. Mining is done by the Longwall system and the coal is hauled to the entrance in cars, by mules. On an average eight men are employed eight months in the year. Some coal is shipped from Franklin.

One-fourth of a mile east of the Marshall bank is the Shaw slope now owned by Sharf Brothers of Monroe, but operated by Gilbert Shaw. Mining was begun twenty years ago, and the lower vein was formerly worked. The upper seam is four feet with a clay parting of four inches near the middle. It has a low dip to the northeast but not sufficient for the drainage of the mine. Seventeen acres are worked out with but one acre

left within the property limits. The method of mining is similar to the Marshall, all the coal being sold locally.

The Edwards slope is a short distance north of the Shaw mine, but has not been operated for some time.

In the southwest ¼ of section 26, is the Barnes slope. The seam is three feet three inches, increasing to four feet in thickness on the rise. It outcrops at various points along a small stream running through the center of the section. The other vein here lies thirteen feet lower down. The coal is divided by a thin clay-sulphur band which is quite persistent. The bank was opened twenty years ago. The Longwall method is used in mining, and operations are limited to four months in the year. The coal is known to underlie 160 acres. The cap rock to the coal seam is a firm band of arenaceous limestone, one and one-half to two feet in thickness, which affords a good roof. This is also a common feature at other mines in the district, although not a constant one.

Near the middle of the north side of section 26, J. M. McConoghey has recently opened a mine not far from the site of the old William Marshall mine. The mine is a slope into a four-foot vein. Sandy limestone overlies the coal. Rolls and partings are common. The seam dips to the southwest. A well defined, nearly vertical, fault running northwest-southeast, displaces the beds with a slip of two feet. Four or five men are employed eight months of the year. Car and man haulage is used and the output is disposed of locally. A lower seam, penetrated in a well at a depth of forty-five feet, is reported to be eight feet in thickness.

In the southwest part of section 36, the coal occurs in the hills bordering the Skunk river flood plain, and a small amount of mining has been done here.

There appears to be a considerable area in this part of the county that is underlain with coal. Some opposition to prospecting is met among property owners but when it is realized that the presence of a workable coal bed enhances greatly the value of farming land, such objection will soon be removed. Prospecting is now being done in section 27 by Shaff Brothers of Monroe.

West of Monroe, along Calhoun creek, in section 32 of Des Moines township, old drifts are seen in the hillsides, and a thickness of twenty to thirty feet of shales and interbedded sandstones may be seen outcropping in the road cuts. The drifts are known as the old Pattison mines, and no coal has been taken out for twenty years. The seam ran about four feet in thickness but water and poor roof caused its abandonment.

Newton district.—The working mines in this district are south of the city of Newton, the largest producers being located near the Monroe branch of the Chicago, Rock Island & Pacific railroad. A great deal of coal has been mined in this neighborhood during the past twenty years, and abandoned drifts, slopes and shafts are common features in the north-central part of Palo Alto township. These are also to be seen at points (indicated on the map) along the main line of the Rock Island railway in this township. There are at present four working mines in this district.

Snooks Brothers' mine is located near the center of section 9. The shaft is fifty-four feet deep, and the coal seam is three feet ten inches to four and one-half feet in thickness. Pinches and swells in the seam are common. The roof is "slate," and considerable timbering is required. The coal is mined by the room and pillar plan. It is hoisted by a gin operated by one horse. The shaft is in two compartments and two screens are provided for sizing. All the coal is disposed of locally. The mine is equipped with a small boiler for pumping when necessary. The mine is operated during but few months in the year. Seventy feet below this seam, six feet of coal are reported.

In the southwest ¼ of section 9, Carson Brothers opened a new mine in 1904. The shaft is seventy-five feet in depth, through blue clay and shale. The seam is four and one-half to five feet in thickness, and is underlain by fire clay, occasionally replaced by soapstone. The slate affords a good roof. The coal bed varies on account of rolls but in general has a low slope to the west. The gin hoist is used. An hour's pumping each day is necessary to keep the mine clear of water. Little coal has been taken from this shaft, it being operated only during the winter months. Twenty-five feet below this mine is a coal bed two and one-half feet in thickness.

Mr. A. Lister formerly operated a mine near the northwest corner of section 8, Palo Alto township, where about twenty acres were mined out in a vein three to four feet thick. The mine now worked is located near the southwest corner of section 3. The shaft is fifty feet deep and two veins are penetrated. The upper is but two inches in thickness while the one mined runs two and one-half to four feet. The two are separated by twelve feet of shales and fire clay. The seams run fairly level, but wedge out entirely 100 yards north of the shaft. The roof is jointed and north-south faults with displacements of one foot or so are frequently encountered. The coal is raised with a one-horse gin hoist. A local trade is supplied. It is necessary to pump three or four hours each day to keep the workings free from water. A 10-horsepower engine is employed, water being drawn by a four-inch belt to which are attached wooden blocks that fit closely and move vertically in a tight box. Ten to twelve men are employed during the winter months.

French Brothers have recently opened a mine in the southeast ¼ of section 15. In prospecting, a four and one-half foot vein was found in four holes, within a radius of 100 yards. The drift and loess are fifty-five feet. In addition there occurred thirty feet of soapstone or slate overlying the coal.

Coal has been mined in two or three drifts in section 7, Buena Vista township, on the land of A. C. Davis. The seam is said to be eighteen inches to two feet in thickness, and water causes much difficulty in mining.

Early coal mining on Cherry creek in section 32, Newton township, has been mentioned. Several old dumps are to be seen in this area, and although some prospecting has lately been done, no coal has been mined for thirty years. Two veins are present, separated by shale. One seam, one and one-half to two feet in thickness, twenty feet above the water, and the other a one-foot seam at about water level. The upper seam lies very close to the glacial drift covering, from which it is often separated by but a few inches of "slate" roof. Deeper drilling encountered no other seams.

From the data obtained at these different mines, it appears that the coal underlies a considerable area in northern Palo Alto

township, extending into Buena Vista to the east, and Newton to the northwest. Where exploited west of the town of Newton, and near Murphy, the seams are thinner and lie higher in actual elevation above sea level. This is in harmony with the strike of the coal-bearing measures. It suggests that the chances are not favorable for coal to the northeast beyond this general line of outcrop; although it may be found in isolated outliers of limited extent. Coal has been found both north and south of Kellogg, which may thus be attributed to detached areas of Coal Measure strata. A prospect hole one-half mile south of Kellogg penetrated six inches of coal at a depth of 129 feet.* It is reported that a shaft put down by a corporation organized in Kellogg, one mile northeast of the town, reached a four-foot vein of coal. Satisfactory corroboration of the details of this statement was not obtained. If coal exists here it is probable that it underlies only limited areas.

Beds of coal which can not with any degree of certainty be correlated with those of the Newton district, less than three miles to the east, have been mined in a small way northwest of the town of Metz, in sections 2 and 3 of Mound Prairie township. Two seams have been worked, both of which give natural exposures. The upper is fourteen inches to three feet thick, and lies almost immediately beneath the drift and about thirty-nine feet above the water in Skunk river. The lower vein runs eighteen inches to four feet in thickness and is at about water level. It is mined intermittently by Mr. A. H. Allfree. The coal thins out to the south, east and north, and is variable in depth. It is usually protected by a sandstone roof, large masses of calcareous ironstone, sometimes septarian in structure, frequently intervene, which cause the coal in places to pinch to a few inches. In the edge of the Skunk river flood plain a twenty-two inch vein was found at a depth of twenty-five feet below the level of the water.

Southwest of Metz, in the southeast ¼ of section 15, Mound Prairie township, a new mine was opened in 1903 by Good Bros. and Collins. It is known as the Fowles mine. The shaft is fifty-seven feet to the bottom of the coal, which runs four to

*Second biennial report of Iowa State Mine Inspector, p. 118. 1885.

four and one-half feet. The Coal Measures lie beneath twenty-five feet of loess and Kansan drift. The roof is "slate" but gives no trouble. The coal is hoisted with a gin, one horse lifting about 1,500 pounds from this depth. One entry has been driven sixty feet north from the shaft. Three men work during the winter months only. The coal is of a good domestic grade and does not clinker.

Prairie City district.—Coal has been mined in the past from country banks at several points over the southwest portion of the county. Those on Calhoun creek have already been mentioned. Near Walnut creek, in the northeast ¼ of section 34, Des Moines township, coal has been mined by a slope in a thirty-inch seam. Trouble with water and a poor roof caused its abandonment.

In the north ½ of section 22, on Walnut creek, are the William White and the C. M. Norris drifts. The White mine is to the west of the stream. The seam lies twenty-eight feet above the creek and averages four feet in thickness. It has a low dip to the southeast. Two feet of jointed slate overlie the coal, and are covered in turn by eighteen inches of limestone "cap rock." About two acres have been mined out. Four to six men are employed during five months of the year.

The Norris mine is located to the east of Walnut creek, and coal has been mined here continuously for twenty-two years. Thirty acres are mined out. The occurrence of the coal is in all respects similar to the White vein. A two-inch "sulphur band" in the coal is a constant feature in this mine. It is necessary to pump three hours each day to remove the water that has accumulated during the previous night. Seven men are employed six months in the year. The quality of the coal from these mines is said to be most excellent, and it is especially good for steam purposes. The output is disposed of locally.

In Vandalia the Cavitt and Pulver mines have operated up to two and three years ago, respectively. There are two seams, one, two and one-half to three feet in thickness, and twenty-five feet lower, a four-foot seam. The former has a shaft sixty-five feet deep, and the latter is a slope to the top vein. In a well

drilling in Vandalia, eighteen inches of coal were penetrated at a depth of thirty feet below this second vein. In the northeast corner of section 30, a small amount of coal has been taken from a drift in the hillside on the farm of A. Lufkin. The seam is twenty-two inches in thickness. Wells in the neighborhood of Vandalia seldom fail to find coal at moderate depths.

One-half mile east of Prairie City, at the north edge of section 1, a drill hole 185 feet deep, penetrated three and one-half feet of coal at the bottom. Mining was not undertaken on account of water.

Colfax district.—Colfax is the center of the most active and extensive mining operations in the county.

The first coal mining in the county was done at the Slaughter bank, one and one-half miles east of Colfax, in the southwest ¼ of section 32, Sherman township. The base of the seam is at about water level in the Skunk river, along which stream it crops out at various points in this vicinity. About thirty acres have been mined, the coal having been taken out through a number of drifts. The seam is six feet thick and dips to the south, two inches to the yard. The roof is slate and is fairly stable. Five years ago a shaft sixty-five feet in depth was sunk, back some distance from the outcrop. The mine was not operated in 1904. The present owners are Hanson and Harrington, who will open it this year. The Slaughter coal has long had the reputation of being the best in Iowa.

Prospecting for the coal in section 5, Mound Prairie township, between the present mine and the railroad, failed in some cases to find it. In others, the drift rested directly on the coal. It has here been removed by erosion, which has detached a small area of the Coal Measure strata from the continuation of the same to the southwest. A drilling sixty-five feet below the coal revealed no other veins.

Coal has been extensively mined along the north border of the Skunk river valley from a point, essentially due north of Colfax, to Valeria. The Jasper County Coal and Mining Company mined out about five hundred acres in sections 34 and 35 of Poweshiek township. Shafts Nos. 2, 3 and 4 (mine No. 1

was a slope), ranging in depth from forty-five to one hundred feet were sunk. The coal within lease limits was practically exhausted. The seam is about twenty-five feet below the level of the river and ranges from three to six and one-half feet in thickness, thinning to the north and finally running out. The roof was slate but this occasionally failed, being replaced by the overlying drift, which made mining very difficult.

In the vicinity of Oswalt several companies have carried on mining operations in this same bed since 1880, when mining was begun in the old Pittsburg shaft by Mr. V. E. Oswalt. The Valeria Coal and Mining Company and its successor, the Diagonal Coal Company, were the largest operators. Their mines have been abandoned for years. Insurmountable difficulties were met in the poor roof and the large amounts of water. Many acres of coal were mined out, but much was left in the workings on account of the improper methods of mining employed.

There are at present but two working mines in the Oswalt district. Warrick Brothers' mine is located in the southwest ¼ of section 34, on the Colfax Northern railroad. The shaft is seventy feet deep to the base of the coal, which is five feet ten inches thick. The coal is overlain by slate which, on account of its jointing, is a dangerous roof. Rolls occur in which the coal thins down to three feet. From the foot of the shaft the seam dips to the north for 300 feet, then rises rapidly till it meets the overlying sand, beyond which it can not be worked. A dip to the southeast from the shaft is also noted. Almost constant pumping is required to keep the mine free from water. The mine is equipped with a gin hoist. The coal is transferred to cars by teams, and an average of four cars per year is shipped. The mine is in operation the year around, employing on an average six men.

The Clover Hill mine, owned by Martin Mindham, is located one-half mile southeast of the last. The shaft was sunk in 1901, and about one acre of coal is mined out. The top of the shaft is thirty feet above the water in Skunk river. The shaft is fifty feet to the coal. The strata penetrated are:

		Feet.
5.	Soil and yellow clay	20
4.	Blue bowlder clay	4½
3.	Coal	1½
2.	Soft slate	25
1.	Coal	4

The vein dips to the north for a distance and then rises. The roof is poor and water is troublesome. The shaft is a two compartment "quarter shaft," to provide for ventilation. The gin hoist is used. One to two cars per week are shipped, and an equal amount is disposed of locally during the six months of operation. The Burris and Davis mine is located on the Pritchard farm, in the northeast ¼ of the southwest ¼ of Washington township. A shaft just being put down at this point penetrates the following strata:

		Feet.	Inches.
13.	Yellow clay, a little gravel	18	
12.	Blue shale	25	
11.	Soft, bituminous shale	2	
10.	Coal		9
9.	Fire clay	4	
8.	Slate, hard, black	30	3
7.	Coal		6
6.	Fire clay, light gray, arenaceous	4	
5.	Slate	16	
4.	Sand rock	4	
3.	Shale, carbonaceous, pyritiferous	25	6
2.	Coal	4	
1.	Fire Clay		

Several prospect holes have been drilled which indicate the presence of the coal under a considerable area. The shaft is eighty feet above the level of Skunk river. The coal seam thus lies about fifty-five feet below the water in this stream. Beneath this vein no coal was found within thirty feet. The shaft will be a two-cage, quarter shaft. It appears probable that this vein is the southwestward continuation of the one mined at Oswalt, on the opposite side of the Skunk river valley, and the same as formerly mined at the old Cooke shaft, a short distance east of Mitchellville in Jasper county.

There are three producing mines in the vicinity of Severs P. O., three and one-half miles southeast of Colfax. Two are operated by the Colfax Consolidated Coal Company and are

reached by the Colfax Northern railroad, and one by Hanson and Harrington, near the northeast corner of section 20, Mound Prairie township.

The last named is known as the "Klondike" mine. The shaft is seventy-two feet to the bottom of the coal. The seam is four feet eight inches thick. The mine was opened seven years ago and about three acres of coal are mined out. The bed dips to the southwest, on an average of one inch to the yard, although it is somewhat undulatory. As a rule, the coal thickens down the dips and thins on the rises. The shaft section is given on page 314.

The shaft is a two-compartment, quarter shaft, but a separate shaft is now sinking to serve as an air and man way. The coal is mined on the room and pillar plan. Shooting from the solid is the practice. The coal is cleaned in the mine and the slack is sent out separately and sold for steam purposes Each room is numbered and the miners are paid for the lump coal by the ton as it is sold over the local scales. One man averages four tons of coal per day. The coal is hard and is a good domestic fuel. Six men are employed during six winter months.

Hoisting is done with a 20-horsepower, Tarrant Marine Engine Works engine. Three hours pumping is necessary to remove fifteen hours' accumulating water. The pump used is a No. 2 Cameron, throwing thirty-five gallons per minute.

As stated earlier, the Jasper County Coal and Mining Company formerly operated mines in the vicinity of Oswalt. Shaft No. 5 of this company was located at Anderson in section 14, Washington township. Fifty to sixty acres were mined out and the shaft was abandoned in 1900. Shaft No. 6 in section 13 was completed this same year. In 1901 a consolidation of the Jasper County Coal and Mining Company and the Colfax Coal and Mining Company was effected, the latter having already its shaft No. 1 in section 17, Mound Prairie township. This last mine then became shaft No. 7 of the Colfax Consolidated Coal Company as the united company is called.

No. 6 is 150 feet, and the coal is three and one-half to six and one-half feet in thickness. The seam is undulatory but has no

pronounced dip in any direction. The roof is "slate" and is fairly stable except where streaked with thin bands of limestone. The latter, which are only one-half to one inch thick, render the roof unreliable in places. The coal is mined room and pillar plan, double entry, with mule and wire-rope haulage. Pumping is done two to three hours each day to keep the workings free from water. Hoisting is done by an 80-horsepower engine, and the coal is run over a one and three-eighths inch screen. At the lower end of the screen is a picking table where bony coal is sorted out, the latter being charged against the miner sending it up. Ventilation is accomplished by means of a fan in a separate air shaft. Eighty acres have been mined from this shaft. An average of 150 men are employed throughout the year.

Shaft No. 7 is on lower ground but works the same seam and is but fifty-five feet deep. The coal is said to run three and one-half to seven feet, and is similar in all respects to that of No. 6. The equipment and methods of mining at this plant are similar to that at No. 6. Water gives some trouble where the roof breaks. One hundred and twenty acres have been mined.

Two shifts are worked in these mines—one going in at 7:30 A.M. and working till 11:30; and again at 12, staying in until 4 P.M. Shot firers go in at 4 o'clock and complete their work at 6, when the night shift goes in and works eight hours.

The output of these mines is all shipped; a spur of the Colfax Northern railroad connects the mines with the main line of the Rock Island at Colfax, and the Great Western at Valeria. The coal is of fair quality. The following is an analysis of a sample of the coal from mine No. 6. The calorific power of the coal is also given. For the purpose of comparison the same data are included for four other well known Iowa coals:

COMPANY AND LOCALITY.	MOISTURE AT 110° C.	VOLATILE COMBUSTIBLES.	FIXED COMBUSTIBLES.	TOTAL COMBUSTIBLES.	ASH.	SULPHUR.	CALORIMETER B. T. U.
Colfax Consolidated Coal Co., Colfax, Iowa	9.34	39.19	39.08	79.27	12.39	2.84	11,206
Whitebreast Fuel Co., Hilton, Iowa	....	40.61	48.21	88.82	11.18	3.26	13,396
Centerville Block Coal Co., Centerville, Iowa	....	37.79	54.85	92.64	7.36	3.29	12,681
Platt Pressed and Fire Brick Co., Van Meter, Iowa	....	40.54	51.04	91.58	8.42	3.68	11,941
Corey Coal Co., Lehigh, Iowa	....	37.98	47.98	85.96	14.04	5.90	12,431

This company controls about one thousand acres of coal land in Mound Prairie and east Washington townships, and the whole has been pretty thoroughly prospected. Workable coal is found to underlie considerable areas in this region. In the northwest ¼ of section 20, Mound Prairie township, shaft No. 8 has just been completed. A vein of five and one-half feet is penetrated at a depth of 180 feet. Entries now being driven have progressed 400 feet from the shaft and active mining will begin as soon as the plant equipment and transportation facilities are in readiness.

Following is a section in a drill hole put down on high ground near shaft No. 8. The churn drill is used by this company in all of its prospecting.

		FEET.	INCHES.
17.	Soil	4	
16.	Clay	26	
15.	Sea mud	13	
14.	Sand	4	
13.	Sandy shale	3	
12.	Blue clay	16	
11.	Soapstone	3	
10.	Sand rock	4	
9.	Soapstone	7	
8.	Slate	10	
7.	Coal blossom		6
6.	Slate	11	6
5.	Coal	1	
4.	Soapstone	7	
3.	Slate	58	
2.	Light slate	3	
1.	Coal	5	

Clay.

Jasper county is well supplied with material for the manufacture of the more common clay wares, building brick and drain tile. The loess has proved suitable for brick and drain tile in various parts of the state. For the manufacture of paving brick, sewer pipe and other vitrified wares, and for pressed brick and hollow blocks, the loess is not suitable. Since the processes in the manufacture of the latter named wares are

somewhat more elaborate, the clays used must possess good plasticity, must stand higher temperatures, and be tough and resistant when finished. Clays of correct composition and possessing the essential physical properties for these wares have been found only in the older formations,—the shale clays, clay shales and fire clays. Those of Jasper county belong exclusively to the Des Moines stage of the Carboniferous, and, as will be pointed out, are favorably exposed in but few localities. In general, the shales of the Coal Measures in the county are sandy and the outcrops to be observed show, almost universally thin beds of shaly sandstone and clay ironstone nodules which make them unsuitable for clay manufacture. Beds of shale of considerable thickness and of uniform character are reported in the sinking of coal shafts in various portions of the area. The fire clay seams which underlie the coal beds may also prove worthy of attention.

Lynnville.—Newby & Macy operate a plant for the manufacture of brick and tile in the southeast part of the town. The clay is a mixture of hillside wash and alluvium, and is taken out near the edge of what is said to have formerly been an old lake. It is free from concretionary lime. A nine and one-half-foot bank is open. Three feet of black soil overlie six and one-half feet of yellow clay. The clay is drawn up a trestle in cars by a winding drum. No definite proportions are observed in the mixing. The plant is provided with a 30-horsepower Ottumwa engine and a 60-horsepower Chicago boiler. The Brewer auger machine is used, with a hand-operated, side-cut delivery table. Brick and tile are made. Of the latter, three-inch, three and one-half-inch, four, five six and eight-inch in size, according to demand. The clay stands drying well without checking. The drying is done in a two-story shed with a capacity for 120,000 four-inch tile. The Warren trucking system is used. The dryer is provided with coils for the utilization of exhaust steam. Ventilation is secured through lifting side-doors. Brick dry in three to four weeks, while but two weeks are required for tile. The burning is done in one Stewart kiln, and one of the ordinary type of round, down draft kilns. The latter has a capacity of 80,000

brick and is equipped with Swift coking furnaces. Tile can be burned in four and one-half days, about two days of which are required for water-smoking.

The outcrops of shales two miles north of Lynnville have been mentioned under the title Geological Formations. A small amount of exploration would, it is believed, locate in this vicinity beds of workable thickness and of suitable nature for the manufacture of clay products.

Monroe.—The plant of G. H. Orcutt is located on Brush creek, one-half mile west of the town. Coal Measure clays are used. The bank consists of a few feet of loess-like drift clay and ten inches to one foot of coal blossom overlying nine feet of fire clay. A ten-inch vein of coal is present five feet below the base of the pit, and this is again underlain by fire clay. Following are the chemical analyses of two samples, one taken in the pit, ten feet from the surface; the second, by a boring about ten feet below the bottom of the pit.

	10 FEET FROM SURFACE. PER CENT.	20 FEET FROM SURFACE. PER CENT.
SiO_2	67.25	70.65
Al_2O_3	18.00	15.90
F_2O_3	4.58	4.23
CaO	.60	.65
MgO	.30	.25
Na_2O	lost	.90
K_2O	2 03	1 00
H_2O at 105°C	.29	.....
Loss at red heat	6.18	5.53
SO_3	. 6	.83
Total	99.79	99.94

It will be noted that the fluxes are not high in either sample, with the exception of iron oxide, but are present in too large amounts to allow of classification as a fire clay. Physical tests were made of these clays, and of two others taken five and twenty-five feet, respectively, from the surface, with results as follows:

SAMPLE.	LINEAR SHRINKAGE IN DRYING.	TENSILE STRENGTH OF DRY CLAY. POUNDS PER SQ. IN.
5 feet from surface	8. per cent	143
10 feet from surface	8.5 per cent	133
20 feet from surface	6.8 per cent	165
25 feet from surface	7.5 per cent	122

This last clay melts at slightly above cone 3, about 1200° C., (2192° F.). The others are all more refractory, the two upper ones burning to a strong buff color. The shrinkage in drying is below the average and there is no tendency to cracking. Their strength and plasticity are high. It should be possible to combine these clays so as to produce a good vitrifying body for paving brick and other vitrified wares.

The buff burning clay was first used for pottery at this plant, and a superior article was produced. Since the clay is plastic and moderately refractory it could be "thrown" with facility, and it will also take a good Albany glaze. At present brick, drain tile and sidewalk tile are made. The clay is picked, and hauled in dump carts to the works where it is put through a seven-foot, American Clay Working Machinery Company dry pan, when dry; and into Brewer rolls when it comes from the pit in a plastic condition. The clays are mixed in the proportions in which they occur in the bank. A Freese auger machine of 25,000 capacity, with side and end cut-offs are used for brick; and a Brewer cutting table for tile. Power is supplied by one 40-horsepower Nagle and a 45-horsepower Lennox boiler, and a 45-horsepower Nagle engine.

The wares are dried in open sheds, and on a floor underlain by small sized sewer pipe laid in gravel, through which exhaust steam is passed. Burning is done in two round kilns: one sixteen feet in diameter, equipped with inside stacks and four fire holes; and the other twenty-four feet, outside stacks and six furnaces. The former holds 18,000 brick, and the latter 50,000. First class products are made here, the blending of the carbonaceous top shale with the fire clay giving the ware a good red color. Five to six hundred thousand brick, some of which are shipped, are made annually, and tile is produced according to the demand.

Kellogg.—Brick and tile are made here by James Holdsworth. The clay is secured south of the Chicago, Rock Island & Pacific track and appears to consist of worked-over loess and Kansan drift. It is hauled by wagon and placed in a soak-pit with layers of sand. A moving belt carries it to a double-shaft pug-auger machine. A hand operated side-cut is used for brick, and a rotary wire cutter for tile. The ware is dried on slatted floors, and burned in two round, down draft kilns.

Newton.—The McAllister Brick and Tile Works is located at the east edge of the city, on the Iowa Central track. The raw material is yellow loess grading into the bluish variety, lying unconformably on a pebbly drift wash. The cut is fifteen to eighteen feet in depth, the whole section being utilized. The clay is drawn to the factory in cars. A New Brewer, No. 9A stiff mud machine is used. An automatic rotating cutter is used for tile and a hand lever cut-off for brick. The auger machine has a rating of 40,000 brick per day. There are five dry sheds, two of these having two floors each and are provided with steam piping. The total drying capacity is about 70,000 three-inch tile. Tile dry in three weeks. A thirteen and one-half-inch tile shrinks in length to one foot in drying. Care is exercised to prevent checking. Two Cooke patent kilns are on the yard. These are round, down drafts and are sixteen and eighteen feet in diameter. The kilns are constructed without bag walls, the gases from the furnaces passing beneath the floor to a central chimney which extends about two-thirds the height of the kiln chamber. The gases then pass downward through the ware and out through openings near the floor into four stacks built into the kiln wall. Firing is done from one side only, in four fire boxes. These kilns are quite satisfactory, the smaller, however, giving the more even burn. The ware produced is strong and durable. It withstands temperatures in the kiln which partially vitrify it, which is unusual with this type of clay. Only tile were made in 1904. There was some demand for sidewalk brick. The plant is operated six months, April to September each year, employing on an average five men.

In west Newton are the brick yards of C. Shamburg and William Henning. Both are located north of, and close to, the Chicago, Rock Island & Pacific track. The so-called "red oak" clay is the raw material at both plants. Banks of ten to twelve feet are open, exposing typical loess passing into the bluish variety below. This lower portion contains lime balls and grades into a sandy joint clay, brown to drab in color, which can not be used. The clay is hauled to soak pits in one-horse carts. The Shamburg yard is equipped with a Creager & Sons' five-mould, soft mud machine; seven rack and pallet dry sheds holding 56,000 brick; and four rectangular cased kilns holding 75,000 to 100,000 brick each. One week is required for drying, and eleven to twelve days for burning. Wood is used for water-smoking and to finish off each burn.

The Henning plant consists of a Horton Manufacturing Company six-mould, soft mud machine; twenty dry sheds; two cased kilns each of 140,000 capacity; and two round, down draft kilns with capacity of 80,000 and 85,000 each. Six men are required to operate the brick machine, besides the sand boy and one man to shovel from the soak pit. 10,000 brick can be made in seven hours.

Baxter.—Brick have been made for sixteen years on the William Henneman yard, three miles west of Baxter, in the southeast ¼ of section 17, Independence township. Loess is used, and examination of a cut fifteen feet in depth shows it to be unusually free from concretionary lime. The clay varies from the yellow color into the gray-blue below. A Henry Martin six-mould, soft mud machine is used. The brick are burned in two open kilns of twelve and eighteen arches. Three kilns per year are made. There is a strong demand for brick in this section. the output of this plant being hauled to Mingo, Ira and Melbourne and Collins in adjoining counties.

Colfax.—Although parties have operated clay plants at several points in this vicinity, the yard of H. Harrington, in the southeastern part of the town, is the only one now in operation. Loess is the raw material and a bank is open in which are exposed twenty-five feet of yellow loess grading into the drab and blue below. Lime concretions are quite plentiful in the upper

portion, and shells of mollusks are abundant. Root casts of limonite occur in the upper, oxidized portions. The clay is carried on cars to three semi-circular soak pits made of brick, eleven to twelve feet in diameter and four and one-half feet deep. The brick are made of soft mud in a Henry Martin, six-mould machine. The latter is mounted on a truck so it can be moved from one soak pit to another on a rail track. Drying is done in open sheds on pallets. The brick are burned in three open kilns and one round, down draft. The product is of fair quality. The plant was not operated in 1904 but the management intends to make brick the coming season.

Stone.

Quarrying has been done at several points in Jasper county in the belt of Red Rock sandstone, which affords the only extensive deposits of building stone in the region. Sandstone from the coal-bearing strata has been quarried at three known localities, section 34, Des Moines township; in a railroad cut in section 30, Fairview; and two miles above Lynnville, in the valley of North Skunk river. At the latter place only is quarrying at present carried on in the county. The exact location is the northeast ¼ of the northeast ¼ of section 34, Richland township. The quarry section at this point has been given on page 312. The sandstone is brown to red in color and is micaceous with small cavities containing fine red ochre or ocherous clay. The total thickness of salable stone is fifteen feet. Considerable stripping of the overlying shales is required. The quarry is worked by William Northcutt. Three hundred perches per year is the output. The stone is durable, and supplies the local demand for cellar and foundation walls.

Stone from the Red Rock formation has been quarried in a number of places in section 17, Rock Creek township. The old Morgan quarry on the land of G. M. Henning was open forty years ago. A face twelve feet in height is exposed, consisting of a heavy bed of brown stone separated from a four foot stratum of compact, reddish-brown sandstone, by two feet of

shattered rock. Similar strata have been worked both above and below this quarry in the valley of Rock creek and its branches.

One mile east of Kellogg the brown sandstone has been quarried quite extensively in the past by the railroad company. Fiteen feet of the sandstone are open to view. Large plans appear to have been made here for the development of these quarries, but no work has been done for years.

Detailed descriptions of the quarry exposures near Murphy and Reasnor have been given under the description of the Red Rock sandstone. Considerable stone has been removed from the Dooley and Lamphear quarries in section 21, Buena Vista township. The latter is now worked intermittently for local use. Both the red and brown varieties are quarried.

On the hill slope one-half mile north of Reasnor, sandstone has been quarried. One mile south of Reasnor, at "Stony Point," the brown sandstone has been quarried in the past.

The most extensive quarrying operations in the county were formerly carried on at the old Kemper quarry in section 8, Fairview township. The rock was quite widely known as the Monroe red sandstone, although both red and brown stone were taken out. John Reinhart took stone from here forty years ago, and worked the quarry for twenty-five years. E. G. Kemper produced, in seven or eight years of his possession, some cut and dressed stone, and at one time employed as many as twenty men. Considerable stone was shipped. The present owner, A. Herwehe, has put out very little stone in the last two years, although there is a fair demand locally.

The following description of the sandstone points out its chief characteristics: *

"It is a moderately coarse-grained stone, with some range of color and texture and corresponds in general with the Red Rock stone which has been more widely marketed. . . . . As will be seen from the tests, it is an excellent stone and might be used to advantage in all structures similar to those in which brownstone has been used so extensively in the east. Under the microscope it seems to be made up of rather coarse

* H. F. Bain: Ann. Rep. Iowa Geol. Surv., Vol. VIII, p. 398.

and rounded grains of quartz cemented by a matrix of red-brown, iron-stained material which, judging from the analysis, is largely ferric oxides, but contains also some aluminous material. The sand grains are rarely in contact; the interstitial areas being usually as large as the cross-section of the individual grain."

The chemical analysis of this stone as given on page 412 of Doctor Bain's paper, is as follows:

SiO_2	84.35	per cent.
Al_2O_3	8.62	"
$FeO + Fe_2O_3$	5.59	"
CaO	.88	"
H_2O + loss	.43	"

A sample of the deep red variety collected by the author analyzed 31.5 per cent of alumina and ferric oxide.

The following composite table gives the results of physical tests of the stone. For comparison data are included for the Lake Superior sandstone, a building material of established reputation. The figures for the Monroe sandstone are taken from "Iowa Building Stones," by Bain in Volume VIII, Iowa Geological Survey Reports; those for the Lake Superior rock from Buckley's "Building and Ornamental Stones of Wisconsin."

	CRUSHING STRENGTH. POUNDS PER SQUARE INCH.	PER CENT OF ABSORPTION.
Monroe sandstone	3,600 3,700	8.64
Lake Superior brown stone	2,001 up to 6,500	4 4 to 15.1

In the Wisconsin drift area and in portions of the northeast townships of the county that have been influenced by the Iowan ice sheet, fresh granite bowlders are abundant and are used for walls and foundations for residences and farm buildings. When shaped and dressed these rocks make very attractive walls, and are eminently durable as well.

Sand.

Attention has been directed to the extensive deposits of sandy loess bordering the Skunk river valley on the east. In places these deposits are practically pure sand and have been utilized for building purposes. On the hilltops one-fourth of a mile north of Reasnor sand has been excavated. In the southeast ¼ of section 13, Elk Creek township, a good grade of clean sand is available. The finest deposit of sand observed in the county is open near the north edge of section 33, Elk Creek township. The sand is stratified and clean, although overlain by several feet of loess. The wind blown sands have, in general, rounded grains and are therefore not as satisfactory where bonding power is essential as are those of angular grain. Where durability and resistance to weather are the chief functions of the filling material, as in ordinary mortar, and for moulding sand where not even these factors are essential, the sands available in Jasper county are quite satisfactory.

Road Materials.

The greatest need for serviceable road materials is felt in those districts, already named, which are covered with fine sand and sandy loess. A mixture of the more plastic loess with such sand in roadbeds would furnish a fair foundation for a surfacing of gravel, crushed rock, or burnt clay ballast. The gravelly Wisconsin drift clay affords a good grade of material for road building, providing proper drainage is accomplished. A gravel pit is opened in section 23 of Clear Creek township.

Available gravel deposits are not well distributed over the county, nor are those observed in the most acceptable locations. A small clayey gravel outcrop is to be seen at the bridge over the North Skunk river in the northwest ¼ of section 35, Malaka township. It apparently lies beneath the Kansan drift and rests unconformably upon the alluvium of the river bottom. A few feet of sand and gravel are exposed in a stream cut in the northwest ¼ of section 4, Poweshiek township, lying beneath

four feet of partially sorted Wisconsin drift. At a few points in the northeast ¼ of section 27, Kellogg township, and in the northeast ¼ of section 22, gravels are exposed along the river valley. They underlie considerable thicknesses of sandy loess and Kansan drift; but if utilized in conjunction with these materials they are valuable deposits. In the southeast ¼ of section 5, Richland township, thirty-seven feet of modified sandy, iron-stained Kansan drift are exposed, covered with ten to twelve feet of loess. The deposit is accessible and may prove of value for road building purposes.

The Red Rock sandstone might be made use of in places for road materials, but crushed rock of this nature has not proven durable as compared with gravel or limestone. The life of a sandstone roadbed is very limited, as the stone does not pack or cement well, and continues to crush under traffic until reduced to sand, with its undesirable qualities.

Clay suitable for making burnt ballast may be found in nearly every portion of the county. No fixed list of qualities is essential to such a clay, nor is it necessary for the usual properties, plasticity, strength and refractoriness to be possessed. The alluvial clays along the streams make a good grade of ballast. The fine-grained "gumbo" phase of the loess, when properly calcined, also furnishes excellent material for road construction.

Ocher.

A deep red ocher has been quarried in the southwest ¼ of the northeast ¼ of section 21, Fairview township. It occurs at the apex of a ridge of the Red Rock sandstone, where the rock is badly weathered. The material itself is impalpably fine, and greasy to the feel, but is intermixed with sand grains. It appears to be the residuum of red iron oxide (Fe_2O_3), the cementing matter remaining from the decay of the sandstone. To be utilizable it would require to be washed free of the sand. It is possible that deposits more nearly free of sand might be located by prospecting along the lower slope of the

hills in this neighborhood. No data were obtained with regard to the production or the disposition of the ocher taken out. It is believed that it might prove of value as a pigment for the manufacture of paint.

Ores of The Metals.

Nuggets of metallic copper are occasionally found in the drift. They are frequently a few pounds in weight and are more common in the Kansan drift than in the later deposits. Several specimens of this nature have been picked up on the farm of Mr. H. Barnes in section 26, Fairview township. A small specimen of ore containing beads of copper and native silver was presented as having been found in the borings from a well on this farm. A sample of vein quartz carrying metallic gold is said to have come also from this well. These samples do not indicate the existence of any amount of similar ore in the region, but are fragments only that have been broken from the parent rocks in localities to the north and carried to their present location by the glaciers which have moved over the region under consideration. The copper ore mentioned has probably come from Keweenaw Point, Michigan, where such materials are known to occur.

The presence of zinc and lead ores in the Coal Measure strata is occasionally reported. Zinc sulphide, sphalerite, is known to occur as concretions similar to iron carbonate and iron sulphide and "clay ironstones," in the shale beds connected with the coal seams. This ore of zinc may be confused with siderite, the carbonate of iron, but specimens have been examined which leave no doubt as to the identity of the mineral and its occurrence in this way. Small cubes of galena, lead sulphide, are also found in ironstone nodules along with iron sulphide and carbonate. These sporadic occurrences of zinc and lead in the Coal Measure beds mean no more as to the presence of minable quantities of these ores than does the occurrence of iron pyrite, for example, in similar surroundings, indicate the probability of workable deposits of this ore. Lead and zinc deposits of importance are not known to occur in this form, nor associated with rocks of this nature.

Water Supply.

The potable waters of the county are drawn largely from the porous strata of the glacial and alluvial deposits. Shallow wells in the loess covered regions obtain a supply in the sands at the base of this deposit, or from beds of gravel and sand which are very commonly found at the base of the Kansan drift. When the latter is the source of supply the wells must be sunk to depths as great at times as two hundred and fifty or three hundred feet. In the river valleys an abundant and durable supply of water is usually obtainable in the sand strata at moderate depths, seldom more than forty feet.

Springs issuing from the Coal Measure strata are not uncommon. The water is, however, often so charged with sulphuric acid as to make it valueless, where it comes from beds associated with coal seams. Two instances may be cited of springs which flow from Coal Measure strata and furnish never failing supplies of good water. In the northeast ¼ of the northwest ¼ of section 9, Rock Creek township, is such a spring flowing from near the base of the Red Rock formation. A spring on the farm of Mr. P. W. Mowry in section 34, Des Moines township, furnishes an abundant supply of most excellent water. Several springs are found in some localities issuing, in many instances, at the contact of the porous loess with the Kansan drift. These afford intermittent and often serviceable supplies for farm purposes.

Flowing wells of moderate depth are to be obtained in certain portions of the county. In all instances the aquifer is some member of the older formations below the Carboniferous. There is a small artesian area where flows are obtained along North Skunk river in sections 26 and 35, Malaka township. There are six flowing wells in this vicinity, two being located on the Riverside Stock Farm in section 35. The water will rise four feet above the level of the flood plain. A number of other wells at higher levels have permanent artesian supply but do not flow. The wells are 145 to 175 feet deep, the water coming from lime and sandstone beds below Coal Measure shales, which are seldom more than six or eight feet in thickness. Occasionally flows

are to be found in other parts of the county, in wells that do not penetrate below the drift, but in which the water rises under hydrostatic pressure, are common.

Attempts have been made in the larger towns to secure increased and more permanent supplies of water by deep drillings into the pre-Carboniferous formations.

The water supply for the city of Newton was formerly drawn from two wells, 1,400 and 1,800 feet in depth. Although a record was kept of the strata in these wells it is not at present available. Professor Norton states* that the supply comes from the Saint Louis beds, reinforced by lower flows from the Maquoketa. While usable for domestic purposes, the water was very corrosive in boilers. The following mineral analysis of the water was made by Dr. J. B. Weems.

	SOLIDS, PARTS PER MILLION.
Silica (SiO_2)	36.70
Ferric oxide and alumina (Fe_2O_3, Al_2O_3)	16.5
Sodium chloride (NaCl)	302.
Sodium sulphate (Na_2SO_4)	2386.76
Magnesium sulphate ($Mg\,SO_4$)	435.86
Calcium sulphate ($Ca\,SO_4$)	1104.89
Calcium carbonate ($Ca\,CO_3$)	87.96
Carbon dioxide (CO_2)	81.30
Total	4451.97

The sanitary analysis of the water is as follows:

	PARTS PER MILLION.
Free ammonia	2.27
Albuminoid ammonia	.186
Chlorine	.183
Nitrogen as nitrites	0.00
Nitrogen as nitrates	0.00
*Solids on evaporation	4716
Solids on ignition	4193
Solids at 180°C	4519

The source of Newton's present water supply is in the Skunk river bottom, five and three-fourths miles southwest of the city, in Mound Prairie township. Eight sand points are driven fifty feet into the alluvial materials of the flood plain, and the water

* Artesian wells of Iowa, Iowa Geo'. Sur., Ann. Rep. Vol. VI, p. 292, 1896.

is drawn from a bed of gravel. The wells are distributed over an area of about 150-foot radius and valves are so arranged that one or all may be pumped from at the same time. The supply is abundant and the quality excellent. The following sanitary analysis of two samples of water from a nearby well drawing from the same aquifer was made by Doctor Weems, May 10, 1903:

	PARTS PER MILLION. 1	2
Free ammonia	1.152	.26
Albuminoid ammonia	.288	.08
Chlorine	....	10.
Nitrites	Tr.	Tr.
Nitrates	8.	5.
Solids on evaporation	246.	298.
Solids on ignition	116.	222.
Oxygen absorbed in 15 min	.06	.24
Oxygen absorbed in 4 hours	.12	.36

The pumping station is located at the wells. The water is forced to the city through an eight-inch pipe line and is lifted approximately 190 feet to the bottom of the supply tank. The latter is supported on a fifty-six foot tower, is sixteen feet deep, and thirty feet in diameter. The present needs of the city are met by pumping four hours per day but the demand is rapidly increasing.

Prairie City formerly drew its water supply from the sands and gravels at the base of the drift. The well was eighty-five feet deep and the supply was ample. So much trouble was given by quicksand that it was found necessary to drill deeper and case the whole to shut out the sand. Drilling was continued through the winter of 1904 and 1905 and at present has reached a depth of 390 feet. A detailed record of the strata passed through was not kept. Examination of cores from different depths gives data which will warrant the following divisions. The record of the railroad well kept by Mr. B. W. Brown was also made use of in this connection.

1. Loess and drift ....85 ± feet.
2. Coal Measure shales and sandstone........140 ± feet.
3. Limestone ....65 ± feet.
4. Coarse, white sandstone.....................2 ± feet.
5. Compact shale.............................63 ± feet.
6. Dense, gray, mg. limestone, penetrated....35 feet.

No. 3 is probably the Saint Louis. The shot drill is used, the core down to three hundred and twenty feet being five inches in diameter; four inches, to three hundred and fifty-five feet, and two and one-half inches, to the present depth.

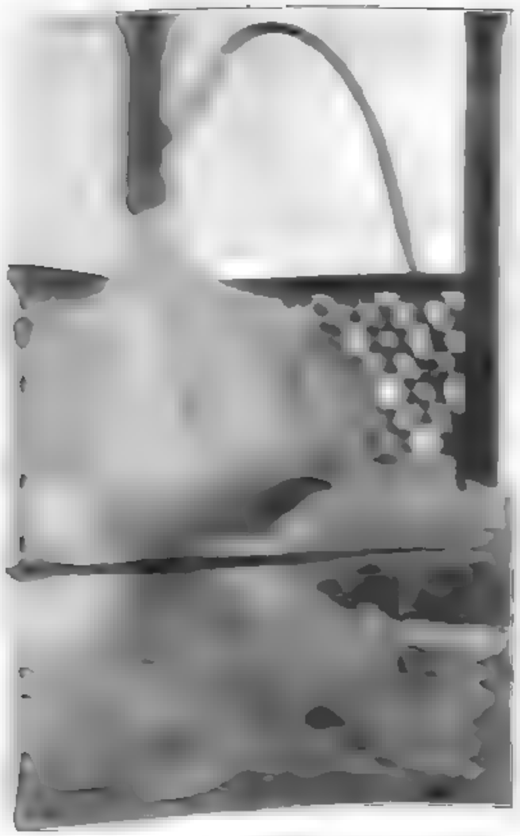
Mineral Waters.

In and near the town of Colfax, flowing wells are obtained at depths of two hundred and sixty to three hundred feet. The quality of the water obtained has given Colfax a wide spread reputation for its mineral water. The water comes from the Saint Louis strata. In sinking the wells three water bearing strata are usually penetrated, but the lowest, reached in the neighborhood of three hundred feet in Colfax, furnishes the mineralized water. An approximate section is given on page 307. The water will rise ten to twelve feet above the Skunk river flood plain.

In the town of Colfax more than a dozen of these wells have been sunk, and are found distributed chiefly among hotels, sanitariums and bottling works. Detailed data regarding four of these wells are given in Professor Norton's "Artesian Wells of Iowa", page 293. There are four bottling works in Colfax: Fryes Bottling Works, Fellows' Bottling Works, Gordon Bottling Works, Crisman Bottling Works. From these establishments are annually shipped to all parts of the country thousands of gallons of the mineral water. The principal hotels also ship large amounts of the water. The estimated output from one of the larger bottling works for one year, exclusive of that sold locally, totals 20,000 gallons.

The water as it comes from the wells contains a small percentage of carbonic acid gas (CO_2) as is shown in the mineral analysis on page 365. This is not sufficient, under atmospheric conditions, to hold the dissolved salts in solution. In bottling,

...with carbon dioxide under ... Special pieces of machin- ... One man can fill eighteen ... The water is shipped also ... By the addition of arti- ... variety of commercial



... natural well, in winter,

... ginger ale, wild cherry

... made by Prof. L. G. Michael, ... sample was kindly submitted ... Hotel, at Colfax. Five gal-

lons of the water were collected and at once hermetically sealed at the well in a stoneware jug.

AMES, IOWA, March 1, 1905.

The following is a report on the water from Colfax well:

GRAMS PER LITRE.		GRAINS PER IMP. GAL.	
CO_2	7.76	NaCl	3.76
SiO_2	0.1275	Na_2SO_4	83.01
Fe	0.00575	K_2SO_4	0.54
Cl	0.034	$MgSO_4$	26.68
CaO	1.0268	$CaSO_4$	32.44
MgO	0.131	$CaCO_3$	99.63
K_2O	0.0042	$FeCO_3$	0.83
Na_2O	0.5458	SiO_2	8.75
SO_3	1.2448	Lithia	——
		*CO_2	594 86

LOUIS G. MICHAEL,
Survey Chemist.

A strict classification of this water would be calcic-saline chalybeate, following the divisions given by A. C. Peale in the 14th Annual Report of the United States Geological Survey. It would also be classed as a "carbonated" water because of the carbon dioxide it contains. When the water is allowed to stand in the atmosphere, or is heated, a coating of iron rust forms in the containing vessel. The precipitation of iron salts also necessitates occasional cleaning of the casings in the wells. Decrease of pressure and the escape of CO_2, along with aeration, cause the precipitation of the iron which probably exists in solution as the carbonate and sulphate.

There is at the present day much speculation among physicians and scientists as to the exact therapeutic value of the different mineral waters. A review of the best information extant on the "Therapeutics of Artesian Waters" is to be found in Professor Norton's "Artesian Waters of Iowa," page 386 *et seq.* A terse summing up at the close of an extended article on the Mineral Waters of Indiana, by Robert Hessler, M. D.,† includes

*CO_2—Weight of gas given off the water when boiled.

†26th Ann. Rep. Indiana Geol. Surv., 1902, p. 159.

the following statements, which are quoted as indicating the trend of the conclusions being reached by investigators in the modern school of "curative physik":

"Mineral waters add nothing to the nutrition of the body which may not also be obtained from the daily food."

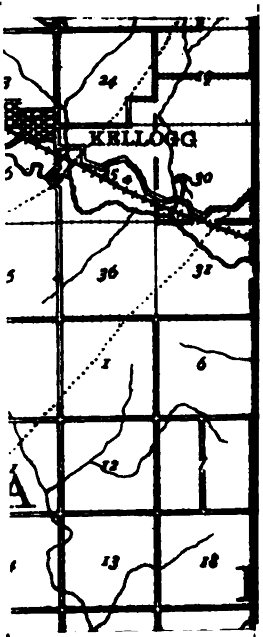
"Although the curative range of our mineral waters is quite limited the number of every day ailments in which they are indicated is large, and many of these mineral waters may be used with good results."

"Sharp distinctions must be made between curative and palliative treatment, and between being benefited and being cured."

"The indications for the use of pure water, and of water only slightly mineralized, are many, those for the use of heavily mineralized waters are comparatively few."

Water Power.

The moderate fall of the larger streams of the county renders available a supply of energy which might be utilized. Data regarding the elevation, slope, volume of flow and available head in both Skunk rivers are given in Part II, Tenth Census of the United States. At present the mill at Lynnville is the only one run by water power.


KELLOGG
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Acknowledgments.

The writer desires to express his thanks to many who have aided in carrying forward the work in Jasper county. Cordial treatment was extended, and information freely given by citizens and officials of the county at all times. Thanks are especially due to Hon. W. O. McElroy, of Newton, and to other city officials for data regarding the city water supply; and to Mr. A. Lufkin, for meteorological data. Mr. Andrew Engle, of Metz, and Mr. W. P. Rippey, of Ira, gave information regarding the deep wells and coal in their respective localities. The officials of the coal companies have been uniformly zealous in rendering all the assistance possible. To Professors Savage and Beyer are the author's thanks due for constant assistance and helpful suggestions during the progress of the field work. The various railroad companies willingly furnished profiles of their lines in the county.

GEOLOGY OF CLINTON COUNTY.

BY

JON ANDREAS UDDEN.

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CONTENTS.

INTRODUCTION.

AREA AND LOCATION.

Clinton county has an area of 880 square miles. It is situated nearly midway between the north and the south boundaries of the state, along the Mississippi river. It extends farther east than any other county in Iowa. Its greatest length in an east and west direction is thirty-eight miles, while from north to south it measures twenty-one miles. The abutting county on the north is Jackson, on the west are Cedar and Jones, on the south is Scott. From the latter county it is separated by the Wapsipinicon river. Its east boundary is the Mississippi river. Clinton county is the fifth of the counties along this great water way counting from the north, and the sixth, counting from the south.

PREVIOUS INVESTIGATIONS.

Visiting and local geologists have both contributed to our knowledge of the geology of Clinton county. Among the earliest geologists whose observations are recorded we find J. D. Whitney, who published some notes on the drift and outcrops of rock along the Mississippi and Wapsipinicon rivers, in Hall's first report on the Geology of Iowa.* Dr. James Hall, who described the general characters of the rock in Iowa in the same volume,† has some references to this county. Dr. J. P. Farnsworth of Clinton has published an account of pockets of fire clay, which were noticed in the limestone in the vicinity of Clinton.‡ Dr. W J McGee made extensive observations on the drift in this county and published an account of his studies in his *Pleistocene History of Northeastern Iowa.*§ In this he de-

* James Hall: Geol. of Iowa, Vol. I, pp. 278-282. 1858.
† James Hall: Geol. of Iowa, Vol. I, pp. 70-71. 1858.
‡ J. P. Farnsworth: Am. Geol., Vol. III, pp. 331-334. 1888.
§ W J McGee: 11th Annual Report U. S. Geol. Surv. part I.

scribes the Goose Lake valley, and also two different drift sheets. In his monograph entitled *The Illinois Glacial Lobe*,* Frank Leverett has published a full account of his studies of the drift in a number of places in Clinton county, especially those bearing on the earlier course of the Mississippi river in the Goose Lake channel.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Clinton county presents several clearly distinguishable areas. The lowlands of the Mississippi, the lowlands of the Wapsipinicon, the Goose Lake valley, the uplands of the Iowan drift, and the uplands of the older drifts, each is marked by different topographic features and is best described separately.

The Mississippi Lowlands.—At the north boundary of Clinton county these lowlands are a little more than a mile wide, on the Iowa side of the river. Following them to the south they widen out to nearly two miles in width in sections 7 and 8 in Spring Valley township. In section 18 in the same township the bluffs again turn toward the river and reach out to its bank in the north part of section 20. This and the extreme northeast corner of the county are the only places where there are no lowlands between the river and the bluffs. From below this point, and all the way to the Wapsipinicon, the bottom lands continue to increase in width, and at the point where the two streams meet they extend two miles away from the Mississippi. The surface of these lowlands is that of a level, alluvial plain, for the most part only about twenty-five or thirty feet above the level of the river, with a general slope to the south of less than one foot to the mile. Near Camanche and near Follets there are remnants of old terraces which rise about thirty feet above the level of the flood plain. It is evident that the entire valley of the great river, which reaches a width of six miles, was once filled to this height, and that the river

* Leverett: Mon. XXXVIII, U. S. Geol. Surv., pp. 466-467. See also Frank Leverett, *Old Channel of the Mississippi in Southeastern Iowa*. Annals of Iowa, Vol. V. pp. 38-51.

has again removed nearly all its old deposits down to the present level of the alluvial plain. Another remnant of the same old terrace lies in the southwest corner of section 30, about one mile north, and one-half mile west, of Midland Junction.

To the southwest of Clinton an island-like part of the uplands is cut off from the main upland to the west by a valley about one-half mile in width. This valley connects with the Mississippi bottoms at both ends, and it is drained by a small stream known as Hart's Mill creek. Its origin dates back to a time when the drainage of the Mississippi was impeded, and its waters flowed over several long and low sags to the east. The opening up and the lowering of the Mississippi valley farther down was evidently so slow and gradual that the river was able to maintain and widen out several channels in this region at one and the same time. The relation of the Hart's Mill valley to the other lowlands leaves no doubt that it is the result of the work of the river; and the size of the valley makes it clear that it can never have held more than a part of the great stream at one time. The strip of upland extending to the southwest of the city of Clinton was thus at one time a high island in the midst of the Father of Waters.

The Wapsipinicon Lowlands.—The Wapsipinicon river enters Clinton county in section 7 of Liberty township. The width of its bottom lands at this place is about one mile, and this continues as far down as the village of Toronto. Below this place the channel widens to more than two miles, sometimes to nearly four miles, as between Wheatland and Calamus, and at a place about three and one-half miles north of Calamus. This wide bottom is again contracted to less than one mile near the north boundary of Scott county, east of Dixon. From this point all the way to the Mississippi, the valley is open, varying from two to four miles in width. The surface of the Wapsipinicon flood plain is mostly from fifteen to twenty-five feet above the low water mark in the river. Nearest the channel its surface is frequently indented by ox-bow lagoons, that mark lines formerly followed by the main channel. Within the limits of the county this flood plain descends at the rate of about two and one-half feet to the mile towards the Mississippi.

The Iowan Drift Plain.—About two-fifths of the uplands of Clinton county consist of a plain which has an average elevation of about 680 feet above the sea, and which ranges from 620 to 760 feet. This plain has a relief which is quite different from that of the other uplands. Its surface is somewhat uniformly level and but little dissected by erosion. There are extensive flat lands with now and then some low ridges that have a tendency to extend from the northwest to the southeast. This we call the Iowan drift plain, for its boundaries coincide with the boundaries of the area that is covered by the Iowan drift. It occupies a belt that extends in a general direction from the northwest to the southeast, and ranges from six to ten miles in width. On the west it enters the county in Liberty township. Here its southern boundary lies in section 31, extending to the east-southeast for three miles, to a point about one mile north of Wheatland. From here it follows the Wapsipinicon river towards the southeast, and crosses this stream near Dixon. It continues with an eastward trend in Scott county to near the confluence of the Wapsipinicon with the Mississippi. The north boundary lies in section 30 in Sharon township, and from there extends east about one mile on the north side of the Chicago Milwaukee & Saint Paul railroad, as far as Lost Nation. From here the north boundary follows a nearly straight line in a direction east-southeast, passing a point about one mile south of Welton to Elvira, and to all appearances meeting the lowlands of the Mississippi some three miles north of Camanche.

The Older Drift Plain.—North of the Iowan drift plain, in the north part of the county, and south of the Wapsipinicon river in Spring Rock township, the land is built up from older drifts and has a different topographic character. Most of its relief lies from 700-900 feet above the sea level. This land is thoroughly dissected, and consists mainly of slopes which follow the ramifications of the drainage and join in ridges between these. In Elk River and Spring Valley townships, along the Mississippi, these slopes are steep and high, sometimes precipitous. Away from the larger valleys they are more gentle with a convex contour above and a concave contour below.

The highest points in the county lie in this drift plain. These are in section 34 in Brookfield township, where the elevation exceeds 920 feet above the sea level, and in section 8 in Hampshire township, where the elevation is about 910 feet. Both of these points lie in the line of the divide between the Wapsipinicon and the Maquoketa basins. In the small tract of the older drift plain which occupies the southwest one-half of Spring Rock township, the most elevated point is located in section 30, and reaches a height of 860 feet above sea level.

The Goose Lake Channel—Goose Lake channel is one of the most interesting features in the topography of the state. It consists of a large stream valley, which crosses the two drift plains from north to south, in the east half of the county. Starting from the Maquoketa river, in Jackson county, it enters Clinton county in sections 5 and 6 in Deer Creek township, and extends from there in a direction a little east of south to near the center of Center township. At this point it turns to a course a little west of south and joins the lowlands of the Wapsipinicon in the southwest corner of Eden township. This valley averages one and one-half miles in width. Its flat bottom lies about one hundred feet below the nearest part of the uplands of the older drift, and from twenty-five to seventy-five feet below the plain of the Iowan drift. It is limited on either side by a well marked line of bluffs. The highest point on the floor of the valley is to the south of Goose lake where its elevation is 690 feet. From this point the surface descends north as well as south. In the latter direction the descent is about six feet to the mile.

DRAINAGE.

Only a small part of Clinton county drains directly into the Mississippi river. This is a strip adjoining the river, nine miles wide at the north boundary and narrowing to five miles near its south end. It includes the townships of Elk River, Hampshire, Spring Valley, Clinton, Lincoln and Camanche. The south end is covered by the Iowan drift. It has a low relief and a sluggish drainage. There are several sections of marshy land north and east of Low Moor, and these cover a

bottom which resembles that of the Goose Lake channel and connects with the latter about two miles south of Elvira. The north end of the belt has a higher relief, and is drained by several small systems of ramifying creeks which lead out to the west bluffs of the great water way.

Along the north boundary of the county another narrow area drains into the Maquoketa river, in Jackson county. The basin of the latter stream extends about two miles into Clinton county, at the northwest corner, but as we proceed eastward it reaches farther to the south so as to include section 1 in Berlin, and section 12 in Welton township. From here its south boundary follows closely the south line of the north tier of townships across Goose Lake channel to section 35 in Deer Creek township, which is the meeting point of the divides that separate the three drainage basins. All of the area of the county not included in these two belts drains into the Wapsipinicon river. The history of the development of the present drainage in this region is exceedingly complicated, and far too much involved to be satisfactorily made out in all of its details at the present time. There are a few general features, however, whose significance is quite clear. In the first place it is evident that some features of the drainage date back to the time preceding the Glacial epoch. There can be no doubt that the main course of the Mississippi river follows a preglacial channel of some considerable stream. So does also the Wapsipinicon river. Many of the creeks in the region of the older drift also occupy valleys that existed before this drift was deposited. Prairie creek, Elk creek and probably Sugar creek are examples of this kind.

But there are other creeks whose present courses have been determined by the drift deposits. Deep creek, which runs for nearly fourteen miles from west to east and follows the north side of a belt of comparatively heavy drift, was in all probability turned into that course by the same drift. The drainage of the Goose Lake channel is of still later origin. It is supposed to date back to a time when the Illinoian glacial lobe pushed across into Iowa from the east, and caused the Mississippi to find a new channel in passing its outer and western border.

This valley now drains a strip of the uplands on either side, a little less than two miles in width. This is the distance to which its lateral gullies have had time to recede or cut back into the old drift plain. The bottom of this valley has a very sluggish drainage. With a slope of only five feet to the mile in either direction north and south, from the divide one mile south of Goose lake, the greater portion of its surface was formerly marshy and is not yet well drained, though several ditches have been constructed for that purpose. There can be no doubt that since the time the channel was abandoned by the stream that made it, accumulations of silt have raised its bottom, which must have had a general descent to the south. At present its surface slopes to the north from a point near Goose lake, and is drained in that direction by Deep creek.

The drainage of the Iowan drift plain is of still later date, and is as a result still less perfect. Its streams have wide and shallow valleys, and marshy ground is frequently seen. The drainage is sluggish. There are even a few small basins without outlets. Along the north border of this drift some valleys extend out beyond it, which are in size out of proportion to the streams that now drain them. These are evidently drainage lines that were once much deeper, and which now lie partly buried under a filling that has accumulated as the drainage became clogged. Silver creek is the most pronounced instance of this kind. Its valley extends north up to Deer creek, and is even continued across and beyond this stream. Deep creek, evidently, now drains a part of what formerly was the north extension of the basin of Silver creek. The Wapsipinicon valley is evidently also following some old and filled channels throughout the greater portion of its course in this county. Northeast of Dixon it perhaps crosses an old divide. Above this place, in the region between Calamus and Wheatland, water stands on its bottoms for weeks during rainy seasons. In the lower part of its course there is an efficient under-drainage in the sands which fill the old channel, and at some points the river almost entirely disappears during stages of low water.

TABLE OF ALTITUDES IN CLINTON COUNTY.

STATION.	ABOVE SEA LEVEL AT STATION.	AUTHORITIES.
Big Rock	697	C., M. & St. P. R.R.
Browns	685	C., M. & St. P. R.R.
Calamus	710	Gannett's Dictionary.
Camanche	725	Gannett's Dictionary.
Charlotte	685	Gannett's Dictionary.
Clinton	588	C., M. & St. P. R.R.
Clinton	593	Gannett's Dictionary.
Clinton—low water	566	Gannett's Dictionary.
Clinton—high water	586	Gannett's Dictionary.
Delmar Junction	822	C., M. & St. P. R.R.
Delmar Junction	811	C. & N. W. R. R.
Dewitt	711	C., M. & St. P. R.R.
Dewitt	687	Gannett's Dictionary.
Elk River Junction	594	C., M. & St. P. R.R.
Elwood	736	C., M. & St. P. R.R.
Goose Lake	703	Gannett's Dictionary.
Grand Mound	710	Gannett's Dictionary.
Lost Nation	744	C., M. & St. P. R.R.
Low Moor	647	Gannett's Dictionary.
Lyons	590	C., M. & St. P. R. R.
Lyons	590	C. & N. W. R. R.
Malone	663	Gannett's Dictionary.
Midland Junction	594	C., M. & St. P. R.R.
Midland Junction	594	C. & N. W. R. R.
Riggs	785	C., M. & St. P. R.R.
Teed's Grove	686	C., M. & St. P. R.R.
Toronto	721	C., M. & St. P. R.R.
Welton	702	C., M. & St. P. R.R.
Wheatland	672	C., M. & St. P. R.R.
Wheatland	686	C. & N. W. R. R.

STRATIGRAPHY.

General Relations of Strata.

The country rock in this county is, almost everywhere, the Niagara limestone. In Spring Valley and Elk River townships this has been wholly removed by erosion in a few places, and the underlying Maquoketa shale is exposed. On top of the Niagara limestone the Coal Measures have once rested unconformably, but these have been almost entirely removed. A few small outliers are left in some places near the north boundary of the county. These sandstones are the latest sediments preceding the glacial drift. The geest, bowlder clay, loess and alluvial deposits constitute the mantle rock, which usually conceals the underlying rocks of the Paleozoic group

except in some places where these rise to an unusual height, or where the drift cover has been washed away by recent erosion. The succession of these formations, as far as known from exposures and explorations in this county, is set forth in the following table:

TABLE SHOWING THE GENERAL RELATIONS OF THE ROCKS EXPOSED IN CLINTON COUNTY.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial.
		Glacial.	Iowan. Illinoian(?) Kansan. Pre-Kansan(?)
Paleozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.
	Silurian.	Niagara.	Gower. Delaware.
	Ordovician.	Trenton.	Maquoketa.

Underlying Formations.

DATA.

The formations enumerated in the above table are all that appear in surface exposures. The Maquoketa shale, which is the lowermost rock, does not come into view in its entire thickness, only its uppermost strata being laid bare in the northeast part of the county. Nevertheless, the thickness of this shale is known from some deep explorations which have been made. These explorations show the nature of the underlying formations to a depth of 1,632 feet below the base of the Niagara limestone.

The Older Clinton Wells.—In the city of Clinton no less than five deep wells have been made. Four of these have been reported on by Prof. W. H. Norton in an earlier publication

of this survey.* His determinations of the formations explored are based on records furnished by drillers and others, and also upon the nature of some samples from the Dewitt Park well and the well put down by the Chicago and Northwestern Railway company. These determinations are given in the table below:

TABLE SHOWING THE THICKNESS (IN FEET) OF THE FORMATIONS EXPLORED IN THE WELLS IN CLINTON, AS DETERMINED BY PROF. W. H. NORTON.

<table>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><th></th><th>FIRST CITY WATER-WORKS, WELL</th><th>DEWITT PARK WELL.</th><th>C. & N. W. R. R. WELL.</th><th>PAPER COMPANY WELL.</th></tr>
<tr><td>Niagara limestone</td><td>120</td><td>90</td><td>130</td><td>224</td></tr>
<tr><td>Maquoketa shale</td><td>180</td><td>140-180</td><td>295</td><td>175</td></tr>
<tr><td>Galena-Trenton limestone</td><td>325</td><td>410-450</td><td>275</td><td rowspan="4">Limerock to 1,075 feet.</td></tr>
<tr><td>Saint Peter sandstone</td><td>100</td><td>40</td><td>60</td></tr>
<tr><td>Oneota limestone</td><td>300</td><td rowspan="2">Mixed limestone and sandstone, 800 feet.</td><td>380</td></tr>
<tr><td>Jordan sandstone</td><td>125</td><td></td></tr>
</table>

The samples of drillings taken from two of these wells are described as follows:

1. *Samples from the Dewitt Park well.*

DEPTH, IN FEET.

10-80..........Buff dolomite.
300-350........Gray and somewhat porous dolomite.
500............Buff dolomite.
680-720........Sandstone, pure, white and soft, numerous larger grains about 0.37 mm. in diameter.
790, 830, 900..Dolomite.
960...........White dolomite, with considerable chert and grains of quartz sand.
1025...........Gray, cherty, dolomite.
1135...........Arenaceous dolomite.

* See Artesian Wells of Iowa, Vol. VI, pp. 241-246.

2. *Samples from the Chicago & Northwestern Railroad Company's well.*

DEPTH, IN FEET.	
400	Hard, gray dolomite.
575	Fossiliferous limestone and reddish shale.
769	White, saccharoidal sandstone, with rounded grains.

Some other descriptive notes are also furnished: The 100 feet of Saint Peter sandstone reported in the first City Waterworks well include some shale as well as sand. In the Dewitt Park well there was some sandstone at the depth of 1,000 feet. and in the Chicago & Northwestern railroad well the 130 feet of Niagara rock is described as consisting of 100 feet of "shelly rock" and 30 feet of "hard rock." Another record of the strata of the first City Waterworks well is given by Mr. D. W. Mead, running thus: drift, 10 feet; Niagara limestone, 290 feet; Hudson River shale, 150 feet; Galena limestone, 275 feet; Trenton limestone, 275 feet; Saint Peter sandstone, 100 feet; Lower Magnesian limestone, 175 feet; Potsdam sandstone, 364 feet.* A second record of the Dewitt Park well given by Superintendent S. M. Highlands is quoted by Professor Norton as follows: Niagara, 150 feet; Maquoketa, 300 feet; Galena-Trenton, 250 feet; Saint Peter, 60 feet.

It is clear that there are some discrepancies in the above records which can not be accounted for except as due to difference in the interpretations on the part of the observers, or else as due to errors in making the measurements. When measurements are made by the drill rods, such errors are not uncommon. In making out the section for the Clinton wells, Professor Norton has, as it seems, taken all such sources of error into consideration and made estimates which find substantial verification from later explorations.

The Latest Waterworks Well.—The latest well for the city waterworks was made in 1902, several years after Norton's report was published. The driller's log describing the rocks penetrated was obtained from the superintendent of the waterworks by the writer. The well was drilled by J. P. Miller & Company of Chicago. This record is given in full on plate VI.

*Notes on the Hydro-Geology of Illinois in Relation to its Water Supply, table XI. D. W Mead.

SECTION OF THE WELL DRILLED IN 1902 FOR THE CLINTON WATER WORKS BY J. P. MILLER. [ELEVATION OF CURB: 588 FT. A T.]

Depth in feet.	Nature of the Rock.	Age of the Rock.
100	Limestone, 125 ft.	Niagara, Silurian.
200 300	Blue shale, 227 ft.	Maquoketa, Ordovician.
400 500 600	Limestone 316 ft.	Galena and Trenton, Ordovician.
700 800	Shale, 14 ft. Caving shale, 92 ft.	Saint Peter, Ordovician.
900 1000 1100	Limestone, 308 ft.	Oneota, Ordovician
	Sandy limestone, 25 ft.	Jordan[?]. Cambrian.
1200 1300	Limestone, 156 ft.	Saint Lawrence, Cambrian.
1400 1500 1600 1700 1757	Shale, 95 ft. Sandstone, 352 ft. Shale, 66 ft. Sandstone, 43 ft.	Basal sandstones and shales, Cambrian.

PLATE VI. Log of the latest well drilled for the city waterworks, at Clinton.

It will be noticed that the difference between this record and that of the first city waterworks well is quite unimportant, and mainly consists in that the later drilling furnishes a somewhat more detailed description than the earlier. The elevation of the curb of this well is about five hundred and eighty-eight feet above the sea level.

Wm. Pitch's Well.—Two more wells in this county extend below the base of the Maquoketa shale. One of these belongs to Mr. William Pitch, and is on the southwest ¼ of section 1, in Brookfield township. This exploration penetrated the following strata:

1.	Yellow clay (drift)	10 feet.
2.	Limestone (Niagara)	160 feet.
3.	Blue shale (Maquoketa)	200 feet.
4.	Limestone of gray color (Maquoketa?)	15 feet.
5.	Black and soft shale (Maquoketa?)	8 feet.
6.	Gray limestone	18 feet.

The Dewitt Well.—The other well is in the city of Dewitt and was made by the Chicago, Milwaukee & Saint Paul Railroad Company. The record of the strata penetrated here is given in the table of well records in the pages following the description of the Geest. (See well No. 42.)

DESCRIPTION OF SECTION.

Believing that differences of interpretation will account for most of the differences shown in the records of the Clinton wells, it must be presumed that such records as most nearly agree with each other are probably nearest to representing the actual conditions. It is, therefore, believed that the close correspondence of the section of the first well with that of the latest made in Clinton, testifies to the correctness of both. The record of the latest well gives a description of the materials penetrated and thus materially increases our basis of known facts upon which the identification of the several members must rest. Making use of the best data at hand, we may describe the different members, which, for convenience, may be taken in order from below upward.

The Basal Sandstones and Shales.—The records of the two wells which have penetrated this lowest formation are not exactly alike. One mentions merely "basal sandstones" while the other gives two sandstones with a combined thickness of two hundred and ninety-five feet. The two are in the latter case separated by fifty-five feet of shale and are overlain by ninety-three feet of the same kind of material, making the total thickness penetrated four hundred and forty-three feet. The same rocks have been explored in the wells in Davenport, and in Rock Island in Illinois. The resemblance of the sections in the three cities is strikingly close. In each instance the upper part of this division consisted of some fine and indurated sediments, which are variously reported as "shale," "indurated sandstone" or "sandy limestone". This is from sixty to ninety feet in thickness. Below this bed there is a water-bearing sandstone, from one hundred and fifty to two hundred and fifty feet in thickness, and this rests again on some fifty-five to seventy-five feet of finer material, sometimes described as a mixture of shale and limestone. Farthest down, in Clinton as well as in Rock Island, is a sandstone explored to depths of from forty to nearly one hundred feet. For a comparison of the three principal explorations in the three cities, the records are placed side by side in the table below. The indicated correlations are necessarily uncertain, but they are suggested by the similarity in the succession. This whole series of sediments is usually referred to the Cambrian age, and they probably belong to the Potsdam series. The following table elucidates this succession:

TABLE SHOWING THE DIVISIONS OF THE BASAL SANDSTONE IN THE CITIES OF CLINTON, DAVENPORT, AND ROCK ISLAND.

Clinton, Waterworks well, 1902.	Davenport, Glucose Factory well.	Rock Island, Mitchell and Lynde's well.
Shale, 93 feet.	Shale, 40 feet. Sandy limestone, 20 feet.	Compact sandstone, 30 feet. Limestone, 35 feet.
Sandstone, 252 feet.	Sandstone, 160 feet.	Sandstone, 130 feet.
Shale, 55 feet.	Shale, 51 feet.	Shaly limestone and shale, 75 feet.
Sandstone, 43 feet.	Not explored.	Sandstone, 97 feet.

Saint Lawrence, Jordan, and Oneota.—Above the basal sandstone and shale, the wells in this region penetrate a magnesian limestone which is five hundred to eight hundred feet in thickness. This rock is somewhat variable in character. It contains an admixture of sand which sometimes increases to the exclusion of other ingredients. Drillers generally report it as limestone, but in places where the sand is copious they sometimes report it as sandstone. In most wells the sand is most abundant near the middle. Keyes has therefore separated these beds into three divisions, which he correlates with the Saint Lawrence, the Jordan, and the Oneota, the two former belonging to the Cambrian series, and the latter being equivalent to what is usually known as the Lower Magnesian limestone of the Ordovician, or Lower Silurian system. The middle (Jordan) sandstone is reported from all the wells that have reached its depth in Clinton, and its thickness, when recorded, varies from twenty-five to one hundred and twenty-five feet. These differences in the reports are probably chiefly due to differences in judgment as to the most suitable terms descriptive of varying mixtures of lime and sand. That the limestone both above and below contains some sand is known from samples of wells in Davenport, although the fact is reported from only the Dewitt Park well in Clinton. The similarity of texture which

characterizes the three divisions sometimes leads drillers to report it under one item as "limestone" or "sandy limestone," and it may yet be questioned whether all three divisions may not be regarded as equivalents of the Lower Magnesian alone. Thirty miles farther south, where this rock measures 800 feet, drillers have found it so uniform in nature that they have described it all under one and the same designation as limestone.

Saint Peter.—This overlies the Oneota limestone, but it is usually separated from the latter by some greenish shale or clay, which in the waterworks well of 1902 is reported as having a thickness of ninety-two feet. Some shale generally also overlies this sandstone and in the above mentioned well this measures fourteen feet. In the other Clinton wells these shales are not reported, but the small development of the sandstone indicates that the shales probably exist, and that they may have been referred to the other formations above and below the sandstone. In Davenport, in Moline, and in Rock Island the shales are present in all wells where detailed records have been made. Probably they have also been penetrated by the deep wells in Clinton. The present writer is inclined to think that they should rather be classified with the Saint Peter, as the thickness of this formation usually varies inversely with the thickness of the shales; and as the combined measure of the three maintains a greater constancy than that of each of the three taken separately, they seem to replace each other.

Galena and Trenton.—These rest on the Saint Peter sediments and consist of dolomitic limestone above with a variable thickness of calcareous limestone below. The latter breaks into thin, flaky fragments under the drill. The measurements in the several wells range from two hundred and fifty to four hundred and fifty feet, owing apparently to differences in the identification of the several observers. The close correspondence between the two most accurate records suggests that these come nearest the facts, one making it 325 and the other 318 feet.

Maquoketa Shale.—The Maquoketa succeeds the Galena upward. Measurements in the different wells range from one hundred and forty to three hundred feet, but some of these measurements are clearly unreliable. In the well in Brook-

field township the drill, after penetrating the body of the shale, went through fifteen feet of limestone and then eight feet of a black shale. In Scott county, and south of the Mississippi, in Illinois, the base of this formation is often very dark and bituminous and this horizon may be the equivalent of the "black shale" under the limestone. It is evident that there may be alternations of shale and limestone between the main bodies of the two formations and this may account for some of the discrepancies in the measurements. The most reliable measurements agreed fairly well, viz: 180, 180, 227 and 223 feet.

Niagara Limestone.—This is the bed rock at Clinton and over almost the entire county. Its upper surface is quite uneven and this may partly account for the extreme differences in the measurements of its thickness in the several wells, which range from ninety to three hundred feet. Three of the wells agree very closely making it 120, 130 and 125 feet respectively at Clinton, and no doubt this is near the correct figure for the altitude of the land where the wells were bored.

In the absence of descriptive records for the most of the wells it seems safest in making a summary estimate of the nature and thickness of the several underlying terranes at Clinton, to average only such as corroborate each other by essential agreement. There is no evidence of faulting, and nothing short of this could account for some of the extreme differences which exist in records.

Summary of the Section.—It seems, then, that in making a deep well in Clinton one should encounter rock materials essentially as indicated below:

		FEET.
13.	Limestone (Niagara)	125
12.	Shale (Maquoketa)	202
11.	Limestone (Galena and Trenton)	321
10.	Shale (age not known)	10
9.	Sand (Saint Peter)	55
8.	Shale (age uncertain)	90
7.	Sandy limestone (Oneota)	304
6.	Sand, with little or no calcareous material (Jordan?)	50
5.	Sandy limestone (Cambrian, Saint Lawrence)	202
4.	Shale (Cambrian)	93
3.	Sandstone (Cambrian)	252
2.	Shale (Cambrian)	55
1.	Sandstone (Cambrian)	43

The Ordovician System.

THE MAQUOKETA SHALES.

Exposures.—The lowest, hence the oldest, rock which comes into view in this county is the Maquoketa shale. It does not cover a very large area, being confined to some places in the valleys of the Mississippi and of the Elk river, in Elk River and Spring Valley townships.

The most southern outcrop is seen in the base of the bluffs of the Mississippi river, just north of the city of Lyons, now included in Clinton. At this place there is seen nearly 100 feet of the yellow Niagara limestone in the cliff of the above mentioned bluff. This rests upon fifteen feet of Maquoketa shale. It is a greenish-gray shale with nodules of iron pyrites and with layers of impure dolomite. The shale is of uniformly fine texture. Under the microscope it was seen to contain occasional crystal-like grains of a bright green color, and also some very minute crystals of pyrites. The particles making up the shale range from .01 to .005 of a millimeter in diameter and fragments measuring as much as 0.1 of a millimeter in diameter are exceedingly rare.

About one-fourth of a mile north of the exposure above described there is another outcrop close to the tracks of the Chicago, Milwaukee & Saint Paul railroad. Here there is a thickness of forty feet exposed. The nature of the material is the same as at the first place, except that the pyrites nodules seem to be more frequent, though of small size. The shale is overlain by about forty feet of yellow limestone.

Another small exposure of the shale, only four feet in thickness, was found along the railroad track near the northeast corner of section 18, in the same township. No fossils were noted in any of these three localities.

In the northwest ¼ of section 20 in T. 83 N. and R. 7 E. some more of this shale was seen along the south side of Elk river. There were eight feet of bluish shale resting on two feet of greenish-yellow disintegrated limestone. In the shale were several bands of dolomitic, bluish limestone measuring from

one to three inches in thickness, and in these layers a few joints of crinoid stems were noted, and also numerous clusters of small cubical crystals of pyrites. The rock was quite impure and contained streaks of bluish clay. The limestone which lies under the clay partakes of the same nature, and exhibits some concretionary lumps of pyrites and other material. On its upper surface there occurs a Pleurotomaria, an Orthoceras, and a great number of poorly preserved fragments of brachiopods and bryozoa.

Along the highway in the southwest ¼ of section 13 in Elk River township, some of this shale is seen in a tributary of Elk river which comes in from the southwest. A thickness of only about four feet is exposed. The shale is greenish-gray in color, and in places it is somewhat indurated. There is some pyrite and a great number of dark, nodular grains of small size, ranging from one to three millimeters in diameter. The texture is variable but approximates the same as is found in other places. In this shale many fossils occur, representing forms like the following:

Pleurotomaria, sp.
Rhynchotrema capax.
Strophomena plicata.
Leptæna rhomboidalis.
Rafinesquina alternata.
Plectambonites sericea.
Orthis biforata.
O. biforata laticosta.
O. occidentalis.
Orthoceras, sp.
Chetetes, sp.
Dalmanites, sp.

On top of this shale there rest at this place two feet of a yellow or bluish-yellow, dolomitic limestone, in which were some pockets of crystalline calcite.

Thickness and Geographical Distribution.—The thickness of the Maquoketa can not be made out from these exposures, but from the data already given in the discussion of the wells it is apparent that this must be about two hundred feet. Its extent of outcrop as a bed rock, underlying the mantle rock, can to some extent be inferred from the topography. The steep bluffs on

the west side of the Mississippi bottoms which extend north from Lyons up to the north boundary of the county, indicate that the valley is now cut below the base of the Niagara limestone this entire distance, and that the shales constitute the bed rock under the flood plain north of Lyons on the west side of the river. In the Elk River valley the cutting has also reached the shale, and in all probability shale underlies the drift for three or four miles up this valley, although it has been laid bare at only a few scattered points.

The Silurian System.

THE NIAGARA LIMESTONE.

AREAL EXTENT.

Excepting the small area just described as underlain by the Maquoketa shale, and leaving out a few patches of still smaller extent of Carboniferous rock, the Niagara limestone is everywhere the bed rock in Clinton county. It underlies the drift over ninety-seven per cent of its entire surface, and there is only one township in which no outcrops of this rock have been noted—the township of Berlin. In the bluffs of the Mississippi rock is almost everywhere seen, and north of Clinton it frequently rises one hundred feet above the level of the river. Over the central and western part of the county the drift has not been so extensively eroded, and the bed rock appears mostly only in scattered places along the water courses. In order to present the details of the various exposures throughout the county the outcrops for the several townships may be described separately.

DESCRIPTION BY TOWNSHIPS.

Berlin.—This is the only township in the county where no outcrops of the Niagara limestone were observed. The land is low and drift covered, and although the rock probably lies at no very great depth, the drift has nowhere been entirely cut through by any of the drainage channels as far as is known to the writer.

Bloomfield.—A little to the northeast of the center of section 1 there are several exposures in the bluffs of Sugar creek. The rock is a much weathered and disintegrated, dolomitic limestone, which contains thin layers of gray chert and casts of *Pentamerus oblongus*, *Halysites catenulata* and some individuals of species of Favosites. On the north side of the creek and a short distance away from it, there are some towers of this limestone, with vertical walls, about thirty feet high. These towers are evidently erosion forms which have been buried under the drift, and are now again exposed by the more rapid removal of the latter. The Niagara limestone was also seen near the same creek one mile farther west, and near the Chicago, Milwaukee & Saint Paul railroad, in section 18.

Brookfield.—Over the central part of this township the drift is heavy and the bed rock is concealed, but it appears at the surface in a few places to the north. In the northwest ¼ of section 11 and in the southwest ¼ of section 12, ledges of weathered rock are seen rising on the slopes of some of the tributaries of Prairie creek. Other places where rock was noted are as follows: In the southwest ¼ of section 1, near the northwest corner of the southeast ¼ of section 2, in the northeast corner of the southeast ¼ of section 17, in the northwest corner of the southeast ¼ of section 5, and in the southeast ¼ of section 8. At the latter place the rock has been quarried by Mr. E. L. Cook. The face of this quarry is about six feet high with two feet of drift stripping above. The rock is a yellow, porous limestone, unevenly and indistinctly bedded. *Halysites catenulata*, *Pentamerus oblongus*, and fragments of an Orthoceras were noted. In the town of Elwood, rock has been found within thirty-six feet of the surface, but at a place in section 9, on J. W. Whilsell's farm, a well went down 250 feet before rock was reached.

Camanche.—On the lower uplands of this township rock is usually not deeply covered and outcrops are moderately common. In the bluffs bordering the lowlands limestone frequently crops out. Most of the surface rock is a porous, disintegrated limestone with frequent pockets of crystals of dolomite. Ledges which lie deeper down are apt to be more

fine-grained and compact. Some of the outcrops examined may be mentioned. In the west bank of Rock creek, in the southwest corner of the northwest ¼ of section 32, ledges of limestone rise to seven feet. In the northwest ¼ of section 25, at one place close to the Chicago & Northwestern railroad, and also on the farm belonging to J. H. Thiessen, irregularly bedded and mostly soft and porous, dolomitic limestone is exposed, and it has been quarried in the place last mentioned. A rock face ten feet in height shows no marked ledges and the rock, which is porous, has some of its cavities filled with a floury form of dolomite. Near the railroad a specimen of *Favosites niagarensis* was noted.

Centre.—The drift is thick in this township, and the bed rock is mostly covered. It comes up to the surface in the east bluffs of the Goose Lake valley, in sections 3 and 10, and is occasionally seen in the bed of a tributary to Brophys creek, which comes in from the west in section 28. On a farm belonging to Mr. C. Kearney there is a quarry near the northeast corner of the southwest ¼ of section 6. This exposes about nine feet of rock, the upper part of which is disintegrated and "shelly," while the lower part is more fine-grained and compact.

Deep Creek.—Along Simmons creek in the northern part of the township there are a number of small outcrops of limestone, and also in the bluffs of Goose Lake channel further south. In the north bank of Simmons creek, in the northeast ¼ of section 15, the limestone forms two columns, which rise some twelve feet above the ground, and are only eight or ten feet wide. It is probable that these columns antedate the time of the deposition of the glacial drift, and their intact existence at the present time is evidence that the flow of the ice at this point must have been very slow and gentle, being too weak to tear down these towers. It is to be remembered that this part of the county lies near to the driftless area, which reaches down to within a few miles in this direction. Two quarries deserve separate mention. One is in section 28, about one-fourth of a mile north of the town of Goose Lake. This has a face of eighteen feet, which consists of a yellow and porous, magnesian limestone of a shattered appearance, without well-defined

ledges, and with streaks of white and powdery dolomite. The uppermost layer of the quarry, for a thickness of three inches, is literally filled with casts and moulds of fossils which are more or less distorted as from pressure. The most frequent forms were *Pentamerus oblongus* and *Halysites catenulata.* A Favosites, a Zaphrentis and a specimen of *Syringopora verticellata* were also noted. The other quarry is on the north bank of Simmons creek, in the northeast ¼ of section 14, and it shows the same kind of rock, which is honeycombed by small cavities set with small crystals of calcite. *Pentamerus oblongus* occurs in this quarry also; and in addition, *Halysites catenulata, Favosites niagarensis* and *Zaphrentis stokesi* were noted.

Dewitt.—In the east part of this township the bed rock is mostly covered. Two exposures were seen in section 12, T. 81 N. and R. 4 E. One of these is just to the north of where the east-west road crosses Cherry creek, and the other outcrop is north of the same road in the west part of the section. In section 12, T. 81 N. and R. 3 E., there are numerous small exposures along the bed of Silver creek. In all of these places the rock is porous and disintegrated, and fossils are scarce. Near the centre of the south half of section 2, to the northwest of the point last mentioned, a small pillar of the limestone rises above the drift. The following section seen on Silver creek, in the southwest ¼ of the southwest ¼ of section 2, T. 81 N. and R. 3 E., is the largest exposure of the Niagara limestone in this township:

		FEET.
7.	Drift	7
6.	Yellow, disintegrated dolomite, with irregular bedding	3½
5.	Fine-grained dolomite of yellow color	1½
4.	Dolomitic limestone in broken laminæ from 1 to 5 inches in thickness	5
3.	Concealed	4
2.	Disintegrated, dolomite rock	4
1.	Yellow, porous limestone forming one single ledge, without distinct bedding planes, and containing specimens of a Zaphrentis, *Halysites catenulata* and *Pentamerus oblongus*	6

In all of the ledges of this section there was evidence of crushing and brecciation, and most of the fossils were in broken fragments. The bedding planes had a dip of 5° to the southwest, evidently an oblique lamination.

Eden.—Most of the land in this township is low, and the bed rock is almost everywhere hidden. Some limestone was noted near the southwest corner of section 6, T. 80 N., near the Wapsipinicon river, also about one-half mile east of Malone, where a small quarry has been opened on the south side of the railroad, and likewise at a point near the railroad about three-fourths of a mile east of Brophys creek.

Elk River.—In sections 5, 8 and 17 in R. 7 E. the uplands terminate in a bluff, sometimes 150 feet high. The face of this bluff consists of the Niagara limestone with the overlying drift. The limestone rises in places as high as one hundred feet. The lower twenty-five feet consist of a dolomitic limestone, in which there are frequent bands of chert, varying in thickness from five to twelve inches. Above this cherty rock is the porous, yellow, often disintegrated dolomite with small cavities frequently lined with calcite crystals. This horizon occasionally contains abundant specimens of *Pentamerus oblongus, Halysites catenulata* and Favosites sp.. Along Elk river the rock sometimes rises in towers resembling those seen in Deep Creek and Dewitt townships, and exceeding these in size. On the farm belonging to Wood and Struve, the following section was noted near the southeast corner of the northeast ¼ of section 12, R. 6 E.

		FEET.
5.	Fine-grained, yellow, dolomitic limestone, unevenly bedded, with numerous bands of chert from two to eight inches in thickness, and frequently containing nodules of chert from one to three inches in diameter	20
4.	Layer of chert	⅔
3.	Thin bedded, dolomitic limestone, containing nodules of chert	4
2.	Brownish-gray, compact and fine-grained, dolomitic limestone; apparently in one single ledge without marks of stratification	10
1.	Dolomitic limestone, gradually changing in color from yellow above to bluish-gray below. The rock readily breaks up into small, angular blocks. Chert nodules measuring from three to four inches in diameter are found	30

At this place the face of the rock shows the effect of solution by water, which has opened crevices along some of the joints, extending into the rock. One of these was large enough to admit of entrance.

On the south side of the creek, near the centre of the north line of section 11, is another exposure of a single ledge of yellow rock, which measures fifteen feet in thickness. This rests on eight feet of laminated limestone. Near the center of the south ½ of section 18, R. 7 E., is a cherty limestone which contains the usual Halysites and Pentamerus together with a number of undetermined brachiopods. About one mile west from this point, in section 13, R. 6 E., there is a small quarry south of the road, on M. D. Shadduck's farm, which shows three ledges as follows:

		FEET.
3.	Yellow, disintegrated, dolomite limestone, with bands of chert	10
2.	Five layers, each a little more than one foot in thickness, and separated one from the other by thin bands of chert	7
1.	Fine-grained limestone, separated into thin layers and containing some chert nodules	15

Hampshire.—In this township a single exposure of limestone was noted on Mill creek in section 34, at a place where a branch comes in from the northwest. The rock was yellow and porous.

Liberty.—The only outcrops of bed rock in this township are in its west half, and near the Wapsipinicon river. The usual phase of the yellow limestone appears in the west bank of the river in section 17. A small quarry has been worked near the highway close to the southeast corner of the southwest ¼ of section 18, and some rock also appears near the southwest corner of section 29.

Lincoln.—In this township more quarries have been worked than in any other in the county. This, in the first place, is due to the local demand for building stone in Clinton. In the second place rock is plentiful in the bluffs of the Mississippi, and many exposures are also found along the creeks farther to the west. The stream beds are sometimes cut in ledges of the Niagara dolomite.

Near the Agatha hospital, in the city of Clinton, there is a quarry with a face about sixteen feet in height and about four feet of drift above. The uppermost three feet consist of a yellow, soft rock, which contains occasional heads and stem segments of crinoids, together with numerous moulds and casts of brachiopod shells. Below this there is more compact stone with small cavities containing crystals of dolomite. This is six feet thick and contains the usual fossils, such as *Zaphrentis*

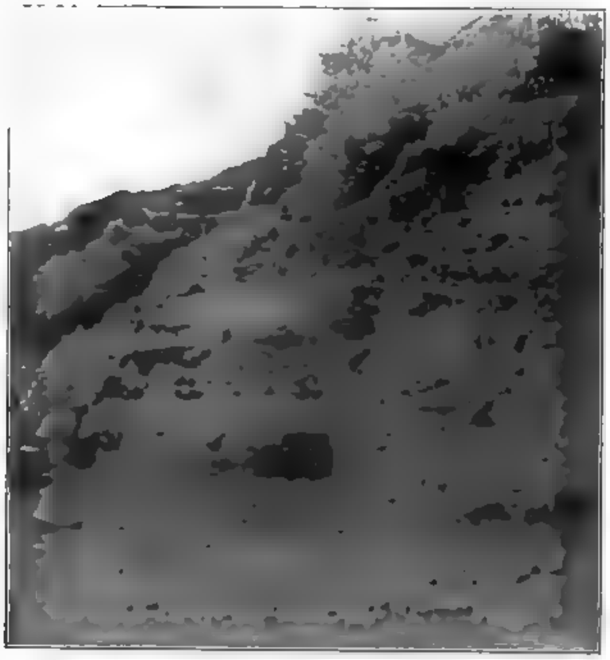

FIG. 81. View showing Niagara limestone in Mr. Peter Gypsum's quarry. Clinton, Iowa.

stokesi, *Halysites catenulata* and *Pentamerus oblongus*. The lower seven feet consist of more evenly bedded and compact, fine-grained ledges of a yellow or sometimes brown color. Several ancient caverns have been exposed by the excavation, one of which was four feet wide and at least five feet deep. All of these caverns are filled with shale of a later age. Ledges having the same appearance, and containing the same fossils as in the above quarry, appear at the foot of the bluff near Fourth

Avenue along the "bluff road", and also in Peter Gypsum's quarry farther to the northeast (Fig. 31). In both of the last two places specimens of an Orthoceras were noted. In D. T. Baldwin's quarry, which lies opposite the Springdale cemetery, the following section is exposed:

		FEET.
4.	Drift	4
3.	Geest	2
2.	Dolomitic limestone, porous and unevenly bedded	6
1.	Yellow and brownish dolomitic limestone, with compact texture and even bedding, containing a fossil resembling *Dawsonoceras annulatus* var. *americana*, an Orthoceras, a crinoid head and joints of crinoid stems, a Heliolites, *Pentamerus oblongus*, and *Halysites catenulata*	5

Olive.—A single small exposure of limestone was noted along Calamus creek; this was in the southeast ¼ of section 2. In the south part of the township rock occurs near the bluffs of the Wapsipinicon river, and has been encountered near the surface in some wells which have been made there.

Orange.—Rock appears in the bed of Barber creek in the southeast ¼ of section 19. The exposure is small, and the ledges are yellow and disintegrated.

Sharon.—This township is covered with a thick deposit of drift, and exposures of the bed rock are not numerous. Nevertheless, a considerable thickness of beds is exposed. An old quarry in the northeast corner of section 18 shows some heavy ledges of the common, yellow dolomite which dip about 7° to the west. Some brownish ledges of the same rock appear along the ravines near the west line of section 18. Rock has been quarried on Henry Kiel's farm, one-half mile northeast of Lost Nation. The ledges are porous, rather unevenly bedded, and contain some chert. Several fossils were noted, such as *Halysites catenulata*, *Pentamerus oblongus*, *Caryocrinus ornatus*, Bumastus sp., and an Orthoceras. The face exposed is only five feet high.

Another quarry from which much rock has been taken is located one-fourth of a mile east of the center of section 15. The rock exposed is as follows:

		FEET.
10.	Drift	5
9.	Geest	4
8.	Fine-grained and laminated rock, breaking along the horizontal seams into slabs from one to three inches in thickness	4
7.	More coarse-grained and porous, evenly bedded, yellow dolomitic rock, without well marked lamination	3
6.	Fine-grained dolomitic limestone, in places with very distinct crystalline texture, and weathering into slabs about four inches in thickness	3
5.	Yellow rock with occasional pockets set with crystals of calcite	4
4.	A single layer of fine-grained, dolomitic rock	3
3.	Brownish, dolomitic limestone of compact texture, breaking much in quarrying, and having occasional crystals of calcite	3
2.	Laminated, fine-grained and compact, dolomitic limestone, breaking into layers one inch in thickness, occasionally bearing chert	1
1.	Solid and compact ledge of gray, dolomitic limestone, with some empty crevices lined with a thin coating of crystals of calcite	2

It is possible that the rock in this section belongs to an outlier of what has been called the Anamosa phase of the Niagara. It is apparently destitute of fossils, and in this respect as well as in its even bedding it differs markedly from the rock in other outcrops in this county.

Spring Rock.—A porous and dolomitic, gray or yellow limestone underlies most of this township and comes into view in several places over the uplands. In the bluffs of Rock Run and east of Big Rock, limestone cliffs measuring ten feet or more in height are not infrequent. Nearly all of the deep wells enter this rock, which is porous and yields water. The elevation of the surface often varies quite considerable in wells that are near together.

Spring Valley.—The Niagara limestone is exposed almost everywhere in the bluffs of the Mississippi river, throughout the entire length of the township from north to south. In the main the same ledges are to be seen, and these belong in the lower part of the formation. The best section is seen where the front of the bluff lies close to the railway grade near the river in the northeast corner of section 30. At this point the following succession of layers was observed.

		FEET.
6.	Drift	5
5.	Geest	3
4.	Porous and yellow, dolomitic limestone, irregularly bedded, full of small crevices lined with calcareous incrustations. This is known as "shell rock" among the quarrymen. In these ledges *Halysites catenulata* and *Pentamerus oblongus* were found	40
3.	Finely granular, yellow, dolomitic limestone with numerous small cavities, often lined with a coating of crystalline calcite. Bands of chert occur at intervals of from two to four feet. Seven of these were each about five inches in thickness	30
2.	Buff-brown, dolomitic limestone of fine-grained texture, with many bands of chert, also scattered nodules of chert. The chert is most abundant below. Some of the chert bands have a thickness of one foot. These thicker bands occur above and the thinner lie below. Thirteen bands in all were counted. The lowermost, of which some were no more than an inch in thickness, lie close together	25
1.	Blue shale (Maquoketa)	15

Washington.—The bed rock is mostly concealed in this region, and there are no extensive outcrops. At two points the usual kind of limestone was noted. One of these was in the northeast ¼ of section 19, near John Tray's place, where the rock comes to the surface on a hillside in the wagon road; and the other was on Cherry creek near the center of section 36.

Waterford.—In the north part of this township, along Sugar creek and its tributaries, there are several exposures of the usual dolomitic limestone, and there are also some outcrops along the minor streams on the uplands. The rock is mostly free from chert, and resembles that commonly found in Lincoln township. Some appears in the railroad cuts near Riggs post office. In the south part of the township the drift is heavier and the bed rock is more generally concealed. There is a small quarry one-half mile east of Quigley post office in section 30, and another near Charlotte. At the latter place about twenty feet of rock are seen. The upper five feet is a coarse-grained, yellow rock, and the lower fifteen feet consists of an almost brown, porous and disintegrated limestone carrying *Pentamerus oblongus, Halysites catenulata, Syringopora verticellata*, a Favosites, and a Zaphrentis.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] from [illegible]
[illegible] per cent [illegible]

[illegible]

[illegible] Delaware stage.

[illegible] Pentamerus [illegible]

[illegible] the base include [illegible]

[illegible] characteristic [illegible]

[illegible] comparatively scarce [illegible]

[illegible] horizon is exposed [illegible]

[illegible] from [illegible]

[illegible] also seen at some [illegible]

[illegible] succession of the two [illegible]

[illegible] Pentamerus beds could not be made out [illegible] that these phases of the Niagara [illegible] horizontally. Most of the exposures of [illegible] the central and the southern [illegible] the upper part of the Delaware stage [illegible] which partake of the appearance of the [illegible] limestone, sometimes exhibiting slightly [illegible] section 1[illegible], Sharon township [illegible] every way resembles the Anamosa limestone [illegible] with the Anamosa [illegible] Jones county, it is perhaps the [illegible] phase of the Niagara known in the state [illegible] Leclaire limestone are known [illegible] quarry, we may suppose that the [illegible] characteristic features as well [illegible] becomes indistinguishable from [illegible] horizon. The highest [illegible] county is not known [illegible] the Pentamerus [illegible] the highest [illegible] seen [illegible]

[illegible]

THICKNESS OF THE NIAGARA.

The surface of the bed rock apparently keeps pace with the dip of the terranes to the south, and the general thickness of the Niagara at the north boundary of the county probably does not fall much short of that along the Wapsipinicon river to the south. In an east and west direction there is a greater difference. In Elk River township the Mississippi river bluffs show nearly one hundred and fifty feet of rock, and at Clinton the limestone extends 120 feet below the bottom land. At DeWitt a well made for the Chicago & Northwestern railroad went into the Maquoketa shale after penetrating 220 feet of limestone. On section 1, in Brookfield township, the Maquoketa shale was entered 160 feet below the upper surface of the overlying limestone. Apparently the greatest thickness of the Niagara formation is in Sharon and Spring Rock townships, and it may here average nearly three hundred feet. The formation gradually thins to about one-half that measure when followed to the east near the Mississippi, as already shown.

The Carboniferous System.

THE DES MOINES STAGE.

After the deposition of the Niagara limestone and of some later sediments of the Devonian age, which latter in all probability once covered the upper Silurian in this region, the bottom of the sea was elevated and became land, which was for some considerable time subjected to general erosion. The elevation was greatest to the north, and it left the terranes with a slight dip to the south. Near the middle of the Carboniferous period this land was again submerged and covered by a new series of sediments. This submergence was greatest to the south, but it is quite clear that it extended north beyond the limits of this county, for Carboniferous sediments are known even in Jackson county. However, nearly all of the Carboniferous deposits have been carried away by later erosion, and there remain only a few outliers of the very base of the rocks of this age, and occasional pockets of clay and sand that fill caverns in the

Niagara limestone. In his paper on the Pleistocene History of Northeastern Iowa, McGee* has mapped a small outlier of the Coal Measures on sections 7 and 18 in Sharon township. The present writer was unable to locate any such outcrop near that point, but several blocks of Coal Measure sandstone were found close together in the base of the drift, near a ravine about one mile farther to the east. There is no doubt an outlier of this rock lies hidden somewhere on these two sections. The sandstone was rather fine-grained.

Near the center of section 2, in Bloomfield township, there appear on the west side of the wagon road running north and south, and in the base of the south bluff of Sugar creek, a thin ledge of white sandstone and some shale. The sandstone is dark and ferruginous in some places. Some blocks of the same sandstone were noted in the east side of the road, close to an outcrop of a highly ferruginous dolomite of the Niagara series. The sandstone on the west side of the road lies some ten feet lower down than this limestone, and this is evidently due to the unconformity between the two formations.

About one-third of a mile east of the northwest corner of section 1 in the same township, the east and west wagon road crosses a small ravine in the east bank of which a sandstone is exposed which measures at least fifteen feet in thickness. This sandstone is rather coarse in texture, of a faintly yellowish-white color, and exhibits some oblique bedding in straight ledges which are mostly about one foot in thickness. A few acres of land appear to be underlain by this rock, and it extends across the line into Jackson county to the north; it evidently belongs to the Coal Measures.

In his paper on the "Carboniferous Deposits of Eastern Iowa," Keyes† makes mention of a small outcrop of Carboniferous rock "on a small branch of Deep creek, in the north-central part of the county, near Charlotte." This locality was not found by the present writer, but no doubt exists as to its presence. Fragments of Coal Measure sandstone are frequently seen in the drift in the north tier of townships west of the Goose Lake channel.

*11th Annual Report U. S. Geol. Surv., Part 1, p. 306.
†Iowa Geol. Surv., Vol. II, p. 469.

One undoubted outlier of the Carboniferous was explored in a well on section 33 in Welton township. This well was made by Mr. J. J. Dickman, at a point about one-third of a mile south of the northwest corner of the section. The materials penetrated were as follows:

		FEET.
6.	Yellow clay	30
5.	Blue clay	20
4.	Quicksand	20
3.	Slate, with seams of coal in the lower part	17
2.	White sand	12
1.	Yellow limestone	4

Number 1 was without doubt the Niagara limestone. Number 2 appears to have been a disintegrated, soft sandstone of the Coal Measures, which changed upward into a shale that contained thin seams of bituminous coal.

As deposits of the Carboniferous age we must also classify certain clays, silts, and sands which have been noted in caverns in the Niagara limestone, especially in the quarries at Clinton. Some of these have already been noted in the descriptions of these quarries, and other instances have been reported and described by Dr. J. P. Farnsworth * and James Hall.† The latter, who was quite familiar with the geology of this entire region, referred these clays to the Carboniferous, and this view is unhesitatingly concurred in by the present writer. Pockets of this kind are frequent in the older limestones in Scott and Muscatine counties. They quite often contain imprints of leaves of Carboniferous ferns, and the clay is often mixed with carbonaceous material such as has been noted in the clays at Clinton.

From the nature of the scattered remnants of the deposits of the Carboniferous age in this region it appears that the geographic conditions were quite uniform. The deposits are such as would result from sedimentation along a low coast. There are no conglomerates, but mainly shales of the finest texture, and sandstones. There can be no doubt, as already stated, that the Coal Measures once covered the entire county,

* American Geologist, Vol. II, pp. 331-334, Fire Clay Pockets at Clinton.
†Geological Survey of Iowa, Vol. I, part I, pp. 130-131, 1858.

and extended a considerable distance beyond its northern boundary. All of the outcrops belong to the Des Moines stage.

EROSION INTERVAL—THE GEEST.

After the Carboniferous had been deposited, the sea once more receded, and the land was slowly raised and tilted again a little more to the south. During the greater portion of the Mesozoic era and the Tertiary period which followed, this land was subjected to erosion which no doubt resulted in the removal of several hundred feet of rocks, of the previous age, and which left the surface of the bed rock essentially in the condition in which we now find it under the drift, athough the occurrence of the Cretaceous deposits farther to the west and to the north indicate the very remote possibility of a temporary submergence in Cretaceous times. The topography of this old land probably had quite as high relief as does the present land surface. The altitudes reached by the bed rock are known to range from four hundred and fifty to seven hundred and seventy feet above sea level, giving a relief of about three hundred feet. But it is clear that this does not represent the extreme relief of the buried land surface. The general slope of this old surface was like that of the present land; from the northwest to the southeast, descending from an average elevation of some seven hundred feet, in Sharon and Brookfield townships, to about five hundred and seventy-five feet in Eden and Camanche townships. The old land surface must have been quite broken and rough, for the elevations at which the bed rock is encountered in wells frequently varies greatly in short distances.

The superficial residual deposits from this erosion interval—called "geest" by McGee—has not always been removed but may sometimes be seen under the drift, resting on the bed rock. The old geest mantle, which resulted from weathering and decay of the Carboniferous and Silurian sediments, is usually a tough, highly ferruginous and red clay, in which pebbles of quartz and chert are imbedded, and also small nodules of oxide of iron. The greatest thickness seen in this county does not exceed four feet. While it is chiefly a residual product, resulting

from the decay of the local rocks, it may be mixed more or less with materials washed from higher slopes by the ancient drainage. The principal localities where it has been noted are given below: Henry Kiel's quarry on the southeast ¼ of section 26 in Sharon township; Anthony Ale's quarry in the southeast ¼ of the northeast ¼ of section 15 in Sharon township; on a slope near the northeast corner of section 30 in Spring Valley township; and in Peter Gypsum's quarry in the city of Clinton. No doubt the geest is exposed also in many other localities in the north part of the county. In many of the deeper wells which have been made, a "red clay" has been reported a few feet thick, directly overlying the limestone. This no doubt also is the "geest." In other wells gravel and sand replace the clay and probably represent deposits contemporaneous with the "red clay." A number of records of the materials explored in such wells are given in the table below. This table likewise contains data on the elevation of the surface of the bed rock in the different townships, and on the nature of the drift deposits:

TABLE OF WELL RECORDS.

Berlin Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
1	Pat Connors. S. ½ Sec. 7.	High upland.	780	172	Sandy soil 30, blue clay 20, sand 120, limestone 2.	610
2	Bowman Bros. Sec 27.	Upland.	720	122	Loess 2, quicksand 100, limestone 10.	618
3	Daugherty Estate. Sec. 4.	High upland.	820	175	Yellow clay 30, blue clay 50, limestone 95.	740
4	Wm. Rock. N. E. ¼ Sec. 23.	Upland.	720	130	Yellow clay 25, blue clay 60, limestone 45.	635
5	Wm. Betts. S. E. ¼ Sec. 38	Upland.	720	70	Sandy soil 30, limestone 40.	650
6	Mary Hassett. S. W. ¼ Sec. 2.	High upland.	760	129	Yellow clay 30, blue clay 95, gravel 4.	631
7	A. Gallaway. Sec. 8.	High upland.	840	326	Black soil 3, yellow clay 30, blue clay 288, red clay 3, limestone 2.	516

Berlin Township—Continued.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated)	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
8	John Foedt. Sec. 24.	Upland.	740	86	Black soil 2, yellow clay 20, blue clay 60, sand 2, limestone 2.	656
9	Peter Peterson. Sec. 18, S. E. ¼.	High upland.	780	210	Black soil 8, yellow clay with sand 40, blue clay 90, quicksand 15, blue clay 110, limestone 5.	575
10	Kohler Bros. Sec. 36, center S. ½.	High upland.	760	180	Black soil 2, sandy, yellow clay 30, blue clay 40, sand 10, blue clay 96, gravel 2.	580
11	J. M. Wolfe. Sec. 36, S. E. cor.	Upland.	740	85	Black soil 8, yellow clay 10, sand 2, blue clay 30, limestone 40.	691
12	J. B. Wolfe. Sec. 6, N. W. cor.	High upland.	760	169	Black soil 4, black gumbo 40, blue clay 100, sand 10, limestone 15.	606
13	H. Schocker. Sec. 8, S. E. cor. S. ½.	High upland.	800	117	Black soil 2, hard pan with coarse gravel 20, blue clay 83, limestone 15.	688
14	P. Twogood. Sec. 26, N. E. ¼, S. E. cor.	Upland.	740	100	Black soil 2, yellow clay 30, blue clay 67, limestone 1.	641
15	M. J. Pinter. Sec. 12, S. E. cor. S ½.	High upland.	840	252	Black soil 2, yellow clay 30, blue clay 190, limestone 20.	608

Bloomfield Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated)	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
16	Jerry Dennis. Sec. 31, S. ½ of N. W. ¼	Upland.	740	170	Black soil 2, yellow clay 40, blue clay 30, limestone 98.	668
17	E. A. Fitch. Sec. 32, N. W. ¼.	Upland.	745	175	Alluvium 2, yellow clay 25, quicksand 144, limestone 4.	574
18	Marvin Fenton. Sec. 19.	Bluffs.	800	150	Yellow clay 30, blue clay 90, limestone 20.	670
19	Alex Narrin. Sec. 29.	High bluff.	840	172	Black soil 2, yellow clay 30, blue clay 90, limestone 50.	718

Brookfield Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
20	Doctor McKinze. Elwood.	Upland.	736	72	Alluvium 6, yellow joint clay 20, gravel and sand 8, hard black clay 15, blue quicksand, very fine 15, black hardpan, 4 gravel 3, limestone 2.	[illegible]
21	George Tesky. Elwood.	Upland.	736	77	Alluvium 7, blue clay 25, black hardpan 20, sandy coarse gravel 1-20, limestone 5.	664
22	W. Webster. Elwood.	Upland.	736	87	Alluvium 5, yellow clay 20, blue clay 25, black clay 20, gravel 10, limestone 7.	656
23	Geo. Benton. Elwood.	Upland.	736	72	Alluvium 2, yellow clay 10, blue clay 20, limestone 40.	704
24	H. G. Scott. Sec. 25, S. E. cor. S. E. ¼.	Upland.	740	110	Alluvium 2, yellow clay 15-20, blue clay 30, limestone 58.	688
25	M. P. Kroosgaard. Sec. 36, N. E. cor. N. E. ¼.	Upland.	740	70	Alluvium 2, yellow clay 27, red clay 8, limestone 33.	708
26	H. P. Christenson. Sec. 30. S. E. cor. S. E. ¼.	High upland.	820	450	Alluvium 2, yellow clay 30, blue clay 400, then a bowlder of iron pyrites 7, blue clay 11.	
27	John Wirths. Sec. 29, S. W. ¼.	Upland.	820	613	First 100 feet unknown, blue clay 100. sand 60, blue clay 300, gravel and blue clay 50, limestone 3.	210
28	Hans Christenson. Sec. 30, S. E. ¼.	Upland.	820	501	Black soil 4, yellow clay 35, blue clay 136, river sand 25, blue clay 100, soapstone 100, blue shale 101.	
29	Wm. Pitch. Sec. 1, S. W. ¼.	Bluff.	780	412	Yellow clay 10, limestone 160, blue shale 200, gray limestone 15, black soft shale 8, gray limestone to bottom 18.	770
30	J. Toskey. Sec. 28, N. ½ of N. E. ¼.	Base of bluff.	800	329	Black soil 2, yellow clay containing bowlders 35, blue clay 100, quicksand 115, blue clay 75, coarse gravel 2.	471
31	C. Ketelsen. Sec. 34.	Bluff.	840	150	Black soil 2, yellow clay 35, blue clay 100, limestone 13.	708
32	J. W. Whitsell. Sec. 9.	Upland.	740	277	Black soil 2, yellow clay 40, blue clay 215, limestone 20.	483

Brookfield Township—Continued.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
33	J. A. Anderson. Sec. 14, S. W. ¼.	High upland	820	815	Black soil 3, yellow clay 30, blue clay 190, quicksand 72, limestone 20.	525
34	H. O. Atzen. Sec. 36.	High upland	820	183	Black soil 3, yellow clay 40, blue clay 100, limestone 40.	677
35	J. D. Limbaugh. Sec. 32.	High upland	820	212	Black soil 2, yellow clay 45, blue clay 161, limestone 10.	618

Center Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
36	Elvira City Well.	Upland.	710	118	Alluvium 5, yellow clay with sandy streaks 50, sandy blue clay 60, sand 3.	
37	Tom McQuire. Sec. 31, S. E. cor. S. W. ¼.	Upland.	715	108	Alluvium 4, yellow clay 20, sand 50, yellow limestone 8, red gravelly sand 20.	
38	Tom McQuire. Sec. 31, S. E. cor. S. W. ¼.	Upland.	715	110	Alluvium 4. yellow clay 30, blue clay 25, rock 10, red gravelly sand 6.	

De Witt Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
39	H. E. Vickery. Sec. 36, S. W. ¼ of N. E. ¼.	Upland.	720	47	Sandy soil 7, yellow limestone 40.	713
40	W. E. McKinney & Co. Sec. 12, N. E. cor. of N. E. ¼.	Upland.	720	60	Yellow clay 12, sand 20, limestone 5, blue clay with sand 23.	
41	Alex. Works. Sec. 19, N. E. ¼ S. W. ¼	Bottom land.	660	26	Alluvium 3, gravel 23.	
42	DeWitt, C. & N. W. R. R. Depot.	Low upland	687	267	Soil and sand 40, limestone 220, shale 7.	647

Eden Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
43	C. Van Epps. Sec. 3, N. W. ¼.	Terrace.	640	172	Sand 40, blue clay 130, gravel 2.	
44	E. B. Wilkes. Tolletts P. O.	Terrace.	620	51	Black clay 2, sandy soil 35, yellow limestone 14.	583

Liberty Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
45	M. Yale Sec. 21, N. E. cor. N. E. ¼.	... .	......	. ..	Alluvium 5, yellow clay 28, yellow limestone 80, fine-grained limestone 20, flinty limestone 20, soft, yellow limestone 12.	
46	P. J. Quade. Sec. 18, S. ½ N. W. ¼.	Upland.	740	60	Alluvium 4, blue clay 30, black hardpan 15, blue clay 4, a large bowlder of lead under which was blue clay 3.	680
47	M. Yale. Sec. 17, S. E. ¼.	Upland.	700	107	Sand 40, limestone 67.	640
48	Ed. Hart. Sec. 34, N. E. ¼.	Upland.	700	48	Sand 3, limestone 45.	697
49	E. Kloidt. Sec. 4.	Upland.	720	100	Black soil 2, yellow clay 30, sand and yellow clay 63, limestone 5.	625
50	J. Figley. Sec. 5.	Upland.	700	100	Sand 70, limestone 30.	630
51	Peter Kulp. Sec. 6.	Upland.	740	80	Black soil 2, yellow clay 35, blue clay 30, limestone 13.	673
52	T. Horstman. Sec. 27.	Wapsipinicon river.	700	175	Black soil 2, yellow clay 35, blue clay 118, limestone 20.	545
53	J. E. Wolfe. Sec. 14, S. E. ¼.	Wapsipinicon river.	700	140	Sand 110, limestone 30.	590
54	Creamery. Sec. 14, S. E. ¼.	Upland.	720	140	Sand 120, limestone 20,	600

Olive Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
55	A. Tumpani. Sec. 11, S. E. ¼, S. ½.	Upland.	700	55	Sandy soil 3, yellow clay 45, soft, porous limestone 7.	652
56	O. F. Ludwigson. Sec. 20.	Upland.	700	230	Sandy soil 100, blue clay 20, sand 108, limestone 2.	472
57	N. O. Olson. Sec. 20.	Upland.	700	175	Limestone at 175.	525
58	Bruce Walker. Calamus.	Upland.	700	137	Black soil 2, yellow clay 20, blue clay 98, limestone 17.	600
59	C. Reming. Sec. 3.	Upland.	720	117	Black soil 2, sand 100, limestone 15.	618

Orange Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated.)	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
60	Grand Mound. City Waterworks.	Upland.	700	88	Alluvium 1, gravel 40, limestone 47.	659
61	C. Munts. Sec. 19.	Upland.	680	60	Sand 60.	
62	P Peterson. Grand Mound.	Upland.	700	67	Sand 45, red clay 2, gravel 20.	

Sharon Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated.)	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
63	C., M. & St. P. R. R. Station. Lost Nation.	Upland.	744	95	Alluvium 7, yellow joint clay 40, yellow limestone becoming harder and lighter in color at bottom, also flinty at bottom 48.	697
64	P. Ahrens. Sec. 10, E. ½ of N. E. ¼.	Upland.	800	183	Alluvium 2-3, yellow clay 30, blue clay 50, limestone 100.	717
65	Chas. W. Comstock. Lost Nation.	Upland.	750	73	Alluvium 2, yellow clay 10, blue clay 20, red clay 2, limestone 40.	726
66	H Dickman, Sec. 9, S. E. cor. S. E. ¼.	Upland.	800	180	Alluvium 2, yellow clay 30, blue clay 100, limestone 8.	768
67	Mrs. H. Lockmer. Sec. 17.	High bluff.	840	210	Black soil 2, yellow clay 20, blue clay 78, limestone 100, about 50 feet down in this limestone a pocket containing blue muck was encountered 2-3.	730
68	Henry Dickman. Lost Nation.	Upland.	740	89	Black soil 2, yellow clay 30, blue clay 36, limestone 20.	670
69	W. Jaronsen. Lost Nation.	Upland.	740	135	Black soil 3, yellow clay 30, blue clay 97, limestone 5.	610
70	J. G. Gardner. Sec. 34, N. E. ¼ N. E ¼.	Creek bottom.	700	137	Black soil 4, yellow clay 4, very fine sand 125, coarse gravel 3.	
71	Jerry Mulverhill. Sec 6, S. E. ¼.	High bluff.	840	140	Black soil 2, yellow clay 35, blue clay 36, limestone 68.	768
72	Wm. Tinnefeld. Sec. 15, S. ½ N. W. ¼.	Upland.	780	137	Black soil 2, yellow clay 30, blue clay 35, limestone 55, chert (hard, white marble) 15.	713
73	Mrs. P. Pitch, Sec. 31, S. W. cor. S. W. ¼.	Upland.	740	140	Sand, fine red 80, limestone 60.	660
74	Wm. Kuehen. Sec. 1, N. W. ¼.	High bluff.	900	140	Yellow clay 40, yellow sand 100, gravel at bottom.	

Spring Rock Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
75	Fred Benk's brickyard, Wheatland.	Upland.	700	87	Alluvium 8, yellow clay 16, blue clay, some places white 48.	
76	Wheatland City Water-works.	Upland.	700	171	Alluvium 5, yellow clay 48, blue clay 39, limestone 4, yellow hard-pan and limestone alternating 50, white, flinty limestone 30.	618
77	Louis Homrighausen. Sec. 28, S. E ¼ of N. E. ¼.	Bluffs.	800	287	Alluvium 90, quicksand 20, blue clay 85, limestone 60.	615
78	Knudt Jergenson. Sec. 25, N. E. cor. N. E. ¼.	Wapsipinicon bottom		245	River sand 60, blue clay 80, black, hard clay 40, blue shale 40, limestone 9.	2
79	City school well. Wheatland.	Upland.	700	177	Alluvial soil 7, yellow clay 44, blue clay 40, limestone alternating with yellow hardpan 60, limestone 26.	549
80	M. Pingel. Sec. 4, S. W. ¼.	High bluff.	800	180	Black soil 1, sand 120, hardpan 2.	
81	D. Pingel. Sec. 4, S. W. ¼ of N. ½.	?		237	Limestone at bottom.	
82	M. Hoffman. Sec. 3, N. E. ¼ in S. W. cor.	?		55	Limestone at 55.	
83	Geo. Buchsel. Sec. 10, N. ½ N. W. ¼.			112	Limestone 22.	
84	G. H. Leffingwell. Sec. 15, S. E. ¼.	?		237	Limestone at bottom.	
85	J. Wohlinberg. Sec. 3, N. W. ¼ in S. E. cor.	?		90	Limestone 20.	

Waterford Township

86	M. Omara. Sec. 18.	Bluff	840	140	Soil 20, limestone 120.	820
87	W. Ward. Sec. 7.	High bluff.	880	120	Soil 20, limestone 100.	860

Waterford Township—Continued.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
88	J. Reife. Sec. 8.	Bluff.	780	190	Yellow clay, limestone 40, blue, mucky shale 40, limestone 80.	750
89	Anton Tur. Sec. 8.	Bluff.	800	160	Yellow clay 6, limestone 154, about 17 feet down in the limestone a a large cavern was encountered.	794

Welton Township.

Number.	LOCATION.	SITUATION.	Elevation of curb (estimated).	Depth.	MATERIALS EXPLORED.	Elevation of bed rock.
90	L. A. Loofboro. Sec. 17, S. E. ¼, S. E. ¼.	Upland.	700	180	Yellow clay 30, blue clay 50, limestone 100.	620
91	W. Rilley. Sec. 16, N. W. ¼.	Upland.	700	130	Black soil 2, yellow clay 20, sand 80, limestone 28.	598
92	P. H. Ryan. Sec. 11, N. E. cor. N. E. ¼, R. 3 E. T. 82 N.	Upland.	780	136	Black soil 8, yellow clay 88, blue clay 30, limestone 40.	764
93	Wm. Betts. Sec. 6.	Upland.	860	140	Drift (?) 100, limestone 40.	760

The Pleistocene System.

The long period of erosion during which the Coal Measure sediments were removed, was brought to an end by the approach of extensive ice fields from the north in the Quaternary age. During this age continental glaciers covered this entire region, probably more than once, and once or twice during that time they overran a part of the area of Clinton county. Each of these incursions deposited a sheet of drift.

PRE-KANSAN STAGE.

Sub-Aftonian or pre-Kansan Drift.—The earliest drift which is known in this state has been called the sub-Aftonian or pre-Kansan. For descriptions of this drift the reader is referred to the reports on several of the counties in the south part of the state, where it is best exposed. It is usually of a dark color and frequently contains fragments of coal and wood, and it lies

under the Kansan bowlder clay. Whether or not it is found in Clinton county must be left an open question. No characteristic outcrops have been observed. The thickness of the drift along a line running west-northwest from Lyons suggests the presence of a morainic belt along that line, and from its location such a moraine can not very well belong to the Kansan, since the ridge does not follow the margin of this drift. It may mark the course of a moraine of an earlier drift,* such as the sub-Aftonian.

KANSAN STAGE.

The Kansan Drift.—In the north part of the county the surface of the drift presents an old appearance. It has suffered extensive degradation by erosion, and the drainage lines have invaded the drift plain until less than one-fourth of its original surface is now intact. Under the loess which lies uppermost there is a yellow or gray till, or bowlder clay, which in all respects resembles the Kansan in other parts of the state. Its upper surface is mostly leached and oxidized to a depth of several feet below the base of the overlying loess. Its most reliable distinctive characteristic for this county is probably to be found in the nature of the rocks represented, in its pebbles and larger erratics. These are the same that characterize the Kansan drift farther south.. Dolomite limestone is less frequent than calcareous limestone. Among the pebbles measuring one-third of an inch in diameter the latter outnumber the former by nearly two to one. Among the pebbles and bowlders which are less than one foot in diameter, diabase, greenstone and granite are present with nearly equal frequency, and together constitute from fifty to eighty per cent of all the erratics of this size. Among the pebbles which are less than one-half inch in diameter there is usually from five to ten per cent of an arenaceous and calcareous rock of the Cretaceous age. These pebbles contain scales of fishes, and have a tendency to break into flaky chips.

Some details of a rather hurried examination of the erratics in this drift are given in the table below:

*See "The Illinois Glacial Lobe," Mon. XXXVIII, U. S. Geol. Surv., by Frank Leverett, p. 144 *et seq.*

COMPOSITION OF THE ERRATICS IN THE KANSAN DRIFT IN EASTERN IOWA.

(The table gives the per cent of erratics of each kind of rock among the different sizes.)

KINDS OF ROCKS.	DIAMETER OF PEBBLES IN INCHES.						
	ONE MILE NORTH OF BIGG'S STATION, CLINTON COUNTY.				One-half mile north of Delmar.		North of Lowden
	9	3	1	⅛	1	⅛	⅛
Limestone Dolomite	2	14	32	22 14	17	15 7	11 5
Sandstone	1	....	3	....	1	....	2
Shale	....	....	1	....	....	....	1
Ferruginous concretions	...	....	....	3	4	....	....
Cretaceous rock	....	....	....	9	5	4	7
Chert	1	2	6	4	2	2	11
Schist	3	3	1	2	1	1	4
Quartzite	5	5	10	3	2	....	11
Diabase, gabbro, etc	15	17	10	30	24	20	19
Greenstone	36	30	23	8	23	23	9
Granite	36	27	9	9	20	23	12
Vein quartz	....	2	4	6	1	5	8

The Kansan drift was laid down over the entire area of the county, for we find it not only on the north side but also on the south side of a later drift. The Kansan drift is known to have come in with an extensive ice field from the northwest, and this accounts for the frequency of pebbles of Cretaceous material. It seems likely that these may have come from some part of the plains several hundred miles farther north.

ILLINOIAN STAGE.

The Illinoian Drift.—Some time after the deposition of the Kansan drift, a lobe of an extensive ice field, coming from the northeast, is known to have advanced westward across the present course of the Mississippi river to the south of this region. The drift left by this ice is known as the Illinoian, and it covers parts of Scott, Muscatine, Louisa and Des Moines counties. It is believed that this drift has been recognized as far north in Scott county as to within a few miles of Clinton county.* In

*Geology of Scott county. W. H. Norton, Iowa Geol. Surv., Vol. IX, p. 480. The Illinois Glacial Lobe, Frank Leverett, U. S. Geol. Surv., Monograph XXXVIII, p. 84.

Clinton county it is probable that this drift also exists, but its presence has been obscured by the later deposits. The Illinoian drift is characterized throughout western Illinois and in eastern Iowa by a high percentage of dolomitic material among its smaller erratics. Of the pebbles which measure less than one inch in diameter, from fifty to eighty per cent are of this kind of rock. If the Illinoian drift occurs in this county at all, it should be found in the townships bordering on the Wapsipinicon and the Mississippi rivers. No certain evidence of the presence of this till has been noted.

IOWAN STAGE.

The Iowan Drift.—Long after the Illinoian ice had disappeared there was an incursion of glacial drift from the west along the lowlands of the Wapsipinicon. This was brought by a tongue of the Iowan ice field which apparently reached as far out as to the present course of the Mississippi river, or perhaps even beyond this some distance into Illinois.* The topographic character of this drift has already been described. Its average elevation is from fifty to one hundred feet less than that of the Kansan drift plain, it has suffered much less from erosion, and fully two-thirds of the original surface of the plain is yet intact and uninvaded by the drainage channels. Occasionally low ridges rise from its surface and run in a northwest-southeast direction. North and west of DeWitt some of these ridges form belts with a broken topography that is almost morainic in character. Elongated and irregular knolls hem in some small and undrained basins.

Another feature of this belt of drift is the quite frequent absence of loess, which elsewhere covers the bowlder clay. In some places, especially near the ridges just described, and also near the margins of the belt, the loess is present, but it is seldom heavy. Quite frequently it is entirely absent. In such cases the drift forms the soil, and this may be calcareous almost up to the surface, and bowlders appear in the fields. Such bowlders are especially frequent immediately west of DeWitt, and also in Olive, Orange, Eden and Camanche townships. They

*See the Illinois Glacial Lobe, by Frank Leverett, Mon. U. S. Geol. Surv., XXXVIII. p. 151.

were also noted in the southern part of Center, Welton, Berlin, and Sharon townships. The percentages of different kinds of rocks represented among 200 of these bowlders were as follows

	PER CENT
Gabbro and diorite	47
Granite and gneiss	35
Quartzite	6
Dolomite	6
Greenstone	3
Coarse, red granulite	3

These bowlders had an average diameter of about two feet, but they ranged in size from one-half to twice this measure. Such very large blocks as have been noted on this drift in other counties are not frequent, only two having been noted. One of these lies on the east side of the wagon road in the northwest ¼ of section 6 in Orange township. It is of granite, and it is broken into several parts some of which measure ten feet in diameter. Another block of coarse granite was noted in the southwest ¼ of section 30 in Sharon township. This measured about 10 by 12 by 15 feet.

The limits of the Iowan drift are by no means clearly or sharply marked. The boundary on the north side may be said to consist of an ill defined belt from one-half mile to two miles in width, where the distinctive features of the earlier and the later drifts gradually merge, or frequently alternate, without apparent order. The belt is marked by dome-like ridges, called paha, which extend more or less parallel with its course, from the west-northwest to the south-southeast. On the south side west of the Wapsipinicon river some Iowan drift appears to have come down along the valley of Yankee creek, while undoubted Kansan drift was noted on the uplands northwest of Wheatland. Small isolated areas of the earlier drift have also been noted to the west, in Cedar county, by Professor Norton.* They seem to be entirely surrounded by Iowan drift.

*Iowa Geol. Surv., Vol. XI, Geology of Cedar County, by Wm. Harmon Norton, p 313 *et seq.*

GRAVELS.

Gravels of Uncertain Age.—Some gravels which occur in ridges on the Iowan area merit special notice. These are the gravels in the pits worked in the northwest ¼ of section 19, just south of DeWitt, and in the northwest ¼ of section 16, a short distance east of Grand Mound, along the Chicago & Northwestern railway. In the pit which lies nearest the railroad south of DeWitt, the lowest part of the material seen in the south end of the excavation consists of sand and gravel about fifteen feet in depth. This exhibited an obscure but still clearly perceptible bedding or assortment of materials of different degrees of coarseness, into layers which had the very unusual attitude of extending in directions varying from the

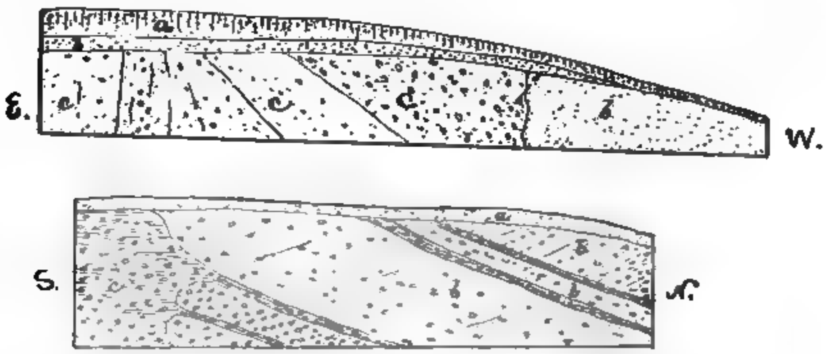

FIG. 32. a. Upper section shows bedding of the drift in the Scott county gravel pit near DeWitt. (a) Sandy loess, (b) ferruginous sand, (c) gravel and sand.
b. Lower section shows bedding in the drift in a gravel pit near Grand Mound. (a) Soil, (b) gravel and sand, (c) bowlder clay.

vertical to inclinations of forty-five degrees. Above this was a two-foot stratum of ferruginous sand, which changed upward into a sandy loess some three feet in depth. The structure is represented in figure 32a. In the pit east of Grand Mound a gently sloping stratification in the gravel seen in the north end of the exposure abuts against an irregular wall of bowlder clay at the south end. From this till some thin layers of bowlder clay run out and are interbedded with the sand and gravel, as indicated in figure 32b. The character of the bedding in both of these instances shows that the gravels are of a glacial origin and were deposited in the presence of ice. The

vertical bedding can have been produced only by disturbances connected with the melting of the ice. In the pit farthest south, near DeWitt, the gravel and sand is overlain by a fine and calcareous silt such as settles in glacial waters. The gravel itself bears clear evidence of being a glacial product, for quite a considerable percentage of the pebbles bear glacial scoring and planing. The question arises as to which age the gravel belongs. The overlying sandy material is, of course, Iowan, and though there is an unconformity between this and the underlying beds, both may very well be derived from the same drift. The ridges are no doubt to be regarded as eskers or kame deposits built up by glacial streams. Were these streams on the Iowan ice or on the Illinoian? This question must be left undecided. Their intimate association with the Iowan drift and their general relation with the Iowan topography render presumptive their identity with this drift. But the material itself very much resembles that found in the Illinoian drift, and in an esker of that drift found in Whiteside county, directly east of the Mississippi. The bulk of the gravel is dolomitic limestone. The results of some observations on the rocks represented in the two principal occurrences of this gravel are given in the table below:

COMPOSITION OF THE GRAVEL IN THE ESKERS SOUTH OF DEWITT.

(Expressed in percentages of fragments of different sizes.)

GRAVEL.	SIZES OF DIAMETERS OF FRAGMENTS IN INCHES.									
	NEAR DEWITT.					NEAR GRAND MOUND.				
	27	9	8	1	⅛	27	9	8	1	⅛
Dolomitic limestone	4	37	77	78	73	18	63	75	75	59
Sandstone and conglomerate	....	..	3	2	..	1	....	....	1	..
Limonitic nodules	....	....	....	....	.	....	....	....	1	1
Chert	..	....	....	5	9	...	....	2	4	18
Schist	..	1	....	2	....	..	....	1	1	....
Greenstone	4	8	2	...	3	1	5	3	4	4
Granite	20	32	5	2	4	14	7	8	4	6
Granulite (red)		1	1	....	...	2	....	1	2	....
Diabase and gabbro	56	9	10	7	8	62	23	10	8	7
Hornblende rock	....	....	1	....	....	....	....	....	....	....
Quartz (vein)	....	....	....	1	3	....	....	....	....	....
Quartzite	16	12	1	3	....	1	2	1	....	3

LOESS.

The Loess.—The loess is the latest deposit on the uplands. It is a yellow or gray, porous material of uniformly fine texture, usually known to well drillers as yellow clay. In the uppermost part it changes into dark soil, which is the universal material seen in the roadbeds on all uplands. When dry it is readily crushed into dust that is easily borne by the wind. It is free from pebbles and coarse sand, but frequently contains calcareous nodules or concretions of most varied forms and sizes. In this county such concretions are not very common. Calcareous material is rather less abundant as an ingredient in the deposit here than elsewhere in the state. North of Clinton the loess occasionally has a purplish tint which is a rather exceptional feature. In the bluffs west of the city of Clinton the writer, some years ago, found a small block of Niagara limestone in the lower part of a freshly exposed wall of the loess in a stone quarry. The block was quite angular and evidently not worn, and as the Niagara limestone rises considerably higher in the hills close by, the suggestion was near at hand that the block might have crept down into its present position. Pulmonate gastropods, which often are frequent in the loess elsewhere, are rare in this county, but not unknown. A few brittle and disintegrated fossils of this kind were seen in the lower part of the loess in the clay pit of the brickyard in the north part of Lyons. The only form indentified with certainty was *Succinea avara* Say.

The loess is universally present on the uplands of the Kansan drift plain, north as well as south of the belt of Iowan drift. It probably averages fifteen or twenty feet in thickness. But in the bluffs of the Mississippi it is heavier than this at some places. In Brookfield and Berlin townships it appears to increase slightly in thickness toward the boundary of the Iowan drift, but this can not be said to be the case along the same boundary east of Welton. The material which forms the upper part of the paha is invariably loess, but it usually changes downward into yellow sand, and even into gravel. Such an instance was noted in a paha in the northwest ¼ of section 29 in Sharon township.

Over the Iowan drift plain the loess is patchy and its tendency is to be absent on the lower parts of the land and to appear in greatest thickness on the higher tracts and on the paha, as already explained. It is believed to be present as a thin mantle in most places, but it probably averages less than one-half the thickness observed on the Kansan drift. A loess-like material was also noted on the alluvial plain of the Goose Lake channel.

ALLUVIUM.

Exposures for the study of the fluviatile deposits are not very frequent. The materials on the surface of the lowest flood plains are almost invariably a silt, largely made up of redeposited loess in the smaller streams. In the Wapsipinicon and the Mississippi bottoms it is occasionally coarser and sandy. Below this silt wells usually penetrate stream sand or quicksand. In the terraces which rise above the flood plain the materials are usually coarser. Such is the case in the terrace near Camanche. In a remnant of a terrace near the Milwaukee railroad at Midland, the bank consists of sand above and gravel below. The composition of the gravel resembles that of the gravels in the Wisconsin terraces, and it seems probable that this is a remnant of the same deposits. The following table shows the nature of the pebbles averaging about one-half inch in diameter in this gravel:

Granite	41
Quartz (one carnelian)	4
Serpentine rock	3
Magnetic iron ore	1
Felsite	1
Diabase	17
Other Keweenawan eruptives	16
Red quartzite (Kew. ?)	4
Gray quartzite	4
Chert	6
Limestone	3
Clay ironstone concretion	1

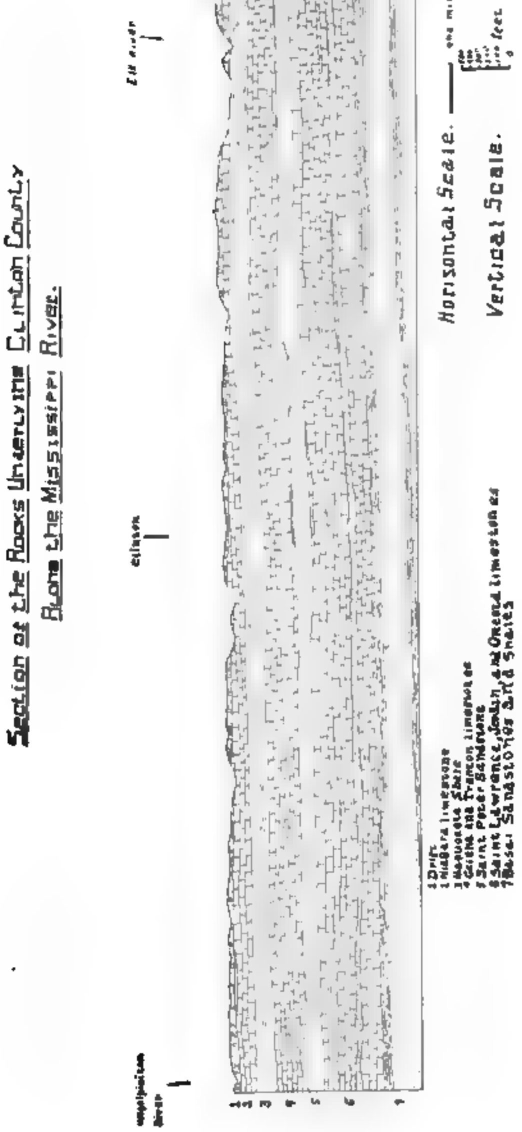

Plate VII. Section of the rocks underlying Clinton county, along the Mississippi river.

Geological Structure.

The Paleozoic terranes in Clinton county have a dip toward the south of about twelve feet per mile, as near as can be made out from measurements within the county. The above statement is based upon data which fixes the elevation of the base of the Niagara at four points lying at the corners of a quadrangle which nearly includes the east two-thirds of the county. In the northeast corner of Elk River township the division between the Niagara and the Maquoketa is known from outcrops, and it averages 600 feet above the sea level. In Mr. Wm. Pitch's well the Maquoketa shale was encountered at an elevation of 610 feet above sea level, practically at the same height as it occurs on the Mississippi twenty-six miles to the east. Again at DeWitt a well entered the Maquoketa at 427 feet above sea level and at Clinton the top of the same shale lies 468 feet above the sea. As DeWitt lies two miles south of the Clinton wells the greater depth of the shale at the former place must be regarded as in part, if not altogether, due to the southward dip, and thus it is clear that in the east and west direction these formations are nearly horizontal. From the north line of the county south to the Clinton wells we may take the distance as twelve miles. The difference in elevation being 132 feet, there must be an average descent of eleven feet per mile. The north and south distance from Mr. Pitch's well to the well at DeWitt being fourteen miles and the difference in elevation of the base of the Niagara being 191 feet, there is an average descent of about thirteen and one-half feet to the mile. The close correspondence of the two figures corroborate their accuracy.

From the exposures in the bluffs of the Mississippi river it appears that this general dip is not uniform. North of Lyons the top of the Maquoketa maintains nearly the same level up to the Jackson county line, so that the strata must lie almost horizontal. Then in the next three and one-half miles to the Clinton wells, the Maquoketa descends 132 feet, or nearly thirty-eight feet to the mile. This comparatively steep dip evidently soon gives place to a more gentle descent of about ten feet to

the mile, for this is required to give to the Niagara the thickness it is known to have twenty miles farther south. See section shown in plate VII.

Minerals.

Some galena and some nuggets of copper have been found in the drift. A specimen of galena was taken up on the farm belonging to Mr. C. Schoff, on section 18 in Brookfield township. Another, which was found on a farm belonging to Mr. A. Evers, weighed ten pounds. Mr. J. W. Hover of Wheatland states that while drilling a well on the farm belonging to Mr. P. J. Quacke in the south half of the northwest ¼ of section 13 in Liberty township, a bowlder of galena was struck at a depth of fifty-three feet. These erratics of lead ore have evidently been picked up by the ice sheet in the lead bearing Galena limestone fifty or a hundred miles to the north, and have been brought here with the drift.

Some small copper nuggets a quarter of an inch in diameter were found in blue bowlder clay sixty feet from the surface, on a farm belonging to Mr. Leonard Clapp, in the west half of the northwest ¼ of section 28 in Sharon township. Such nuggets occur in the drift in other parts of the state and they have probably been transported by the ice from the region of Lake Superior.

A white rock flour is sometimes to be seen in small crevices in the Niagara limestone. It is a form of dolomite. Cubical crystals of iron pyrites are also common in the Maquoketa shale.

ECONOMIC PRODUCTS.

Clay Industries.

The largest brick making establishment in Clinton county is located in the city of Clinton, near First avenue and Fifth street and belongs to Mr. Thomas Price. The clay used is loess, and this is taken from a bluff near by. The brick is hand made

and the clay is prepared in two pug mills. The brick is sun dried, and burned in open kilns. The usual output in one season is 1,500,000 brick. About twenty men are employed. The average price received is $7.00 per thousand. The total output is consumed by the home market.

The Lyons brickyard is located at the foot of the bluffs in the northwest part of the former city of Lyons (now a part of Clinton). The clay used is a yellow loess. There is one pug mill, and the brick are sun dried and burnt in open kilns. From five to ten men are employed, and the output for each season varies from 200,000 to 500,000 bricks, which are sold in the home market at prices varying from $6.00 to $8.00 per thousand.

The tile and brick works near DeWitt belong to W. E. McKinney & Co. The plant is located along the Chicago, Milwaukee & Saint Paul railroad about one-fourth of a mile northwest of the town. Tile as well as brick is made from a yellow, sandy, loess-like material, which rests on drift in a paha ridge. A Brewer and Tiffany, stiff mud machine is run with steam power. From eight to ten men are employed. About 200,000 bricks and 400,000 tiles of two sizes (three and eight inches in diameter) are made in a season. The product is dried in sheds and is burnt in down draft kilns. Part of the output is shipped to outside points and part is sold in the home market. Prices are about as follows: brick, $8.00; three inch tile, $12.00; eight inch tile, $65.

Mr. Fred Rink owns a brickyard in Wheatland, and uses a yellow loess clay. The brick is made with a Leander machine. It is dried in sheds and burnt in a down draft kiln. Four men are employed. About 700,000 bricks are made in a season and sold at $7.00 per thousand in the home market. Some tile is also made, as the market demands.

Sand and Gravel.

Mortar sand is obtained in many places from the drift and also along some of the streams. Near Toronto large quantities are taken each year from the bed of the Wapsipinicon river and hauled away to supply the country to the north.

In the northwest ¼ of section 31 in Elk River township the Chicago & Northwestern railroad operates a large gravel pit. The top layer consists of a moderately fine sand which is partly used for engine sand. Underneath this sand there is from twelve to fifteen feet of gravel, which is coarse enough to be used for road ballast. About five hundred car loads are taken out each year. This gravel is in an old terrace of the Mississippi river.

Gravel suitable for ballast and for building of highways has been found in esker-like ridges in four places over the area of the Iowan drift. Two of these are on the west ½ of section 19, south of the city of DeWitt. The larger of these two is owned and worked by Scott county for road building. This pit is close to the Chicago, Milwaukee & Saint Paul railroad, and the gravel is hauled by this road. About six thousand cubic yards were taken out last season and from three to six men were employed. The other pit on this section lies a quarter of a mile farther south. It is owned by the city of DeWitt and supplies material for gravelling the roads in DeWitt township.

The Chicago & Northwestern railroad once worked a gravel bank on the north side of the road in the northwest ¼ of section 16 in Orange township. This pit at present supplies some road material for the neighborhood of Grand Mound.

Another old gravel pit was formerly worked by the same road near the center of section 23 in Olive township.

The material in all of these places on the area of the Iowan drift consists mainly of dolomitic limestone. There are several other ridges which contain the same kind of gravel, in the region near the Wapsipinicon river. These will no doubt be utilized when the supply in the present pits has been exhausted.

Building Stone.

There are a great number of small stone quarries throughout this county. None are worked on a large scale. No building stone is exported, and such quarries as these, merely supply the local demand for curbing, riprap, road making and flagging stone. All the rock quarried comes from the Niagara formation. While this in many places can be taken out in blocks suitable for building stone, it is not suitable for dimension work. One reason for this is the fact that in nearly all of the quarries the several layers vary in thickness as they are followed horizontally. Quite often the rock is too porous and too soft to stand weathering. The largest quarries are in Clinton, but even these are not worked during all of the year. Openings have been made in many places in the bluffs where no work is now going on. Throughout the county, openings for small quarries are so generally distributed in every neighborhood that there has been no centralization of the industry in any particular place. The value of the entire output probably does not exceed $7,000 a year, and no more than a dozen men are employed in the work.

Water Supply.

On the alluvial or "bottom" lands along the rivers and larger creeks water is obtained in wells which go down into sand. Usually this is encountered within forty feet of the surface. On the uplands the most of the wells are deeper than this. Water is sometimes obtained in sandy or gravelly beds either in the glacial till or immediately below it, but the best wells draw their supply from the Niagara limestone. This latter horizon lies at depths usually ranging from fifty to two hundred feet below the surface. The waterworks in DeWitt, Grand Mound and Wheatland obtain their supply from this rock. The water supply in the city of Clinton is partly from deep wells which tap the Saint Peter sandstone of the Ordovician, and also the Saint Croix sandstone of the Cambrian. Part of the city supply is pumped from the Mississippi river.

Soils.

The soils in Clinton county do not differ essentially from those in the surrounding country. The alluvial plains are covered with a very rich and black soil, but during wet seasons much of the land suffers from insufficient drainage. On the uplands there is less of humus and the soil is not always so black, but it is nevertheless of good quality. Along the north border of the Iowan drift, and near the paha on this drift, there are occasional small patches of sandy soil. Along Elk river, in the northeast part of the county, the land is too hilly for general cultivation, but it furnishes excellent pasturage.

Quicklime.

In earlier years lime was burnt for some time at Lyons and near Camanche, but this industry has now been abandoned. Rock suitable for such purposes is common throughout the county.

Coal.

While there is no doubt that the Coal Measures once covered the Niagara limestone everywhere in this region, it is no less evident that during later ages the rocks of the Des Moines stage have been almost entirely removed, and that the few remaining outliers are altogether too insignificant to contain any workable seams of coal. A coal bearing shale has been reported from a well on section 33 of Welton township, but the seam was thin and no doubt of very limited extent, as the Silurian rocks are known to come up around it on all sides. Money spent in prospecting for coal in this county is certain to bring no returns.

Lead and Copper.

The fragments of galena and copper which have been discovered in this county are erratics from other regions, and do

not signify that such minerals can be found by prospecting. The bed rock is known to be barren and will never yield either base or precious metals.

ACKNOWLEDGMENTS.

The writer, who is responsible for nearly all of the field work in this county, desires to state that the above report has been edited and in part written by his father, Dr. J. A. Udden, who also aided in the field work on the study of the drift.

GEOLOGY OF FAYETTE COUNTY.

BY

T. E. SAVAGE.

GEOLOGY OF FAYETTE COUNTY.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Fayette county was established in December, 1837, and was named in honor of the French Marquis de Lafayette. At that time it was the largest county in the United States.* It included the greater portion of what now comprises twenty-eight of the northern counties of Iowa, nearly all of the present state of Minnesota, and all of the Dakotas east of the White Earth and the Missouri rivers. It embraced a total area of nearly 140,000 square miles. Ten years later the county was reduced to its present boundaries.

Fayette county is situated in the second tier of counties west from the state of Wisconsin, and in the second row south from Minnesota. Winneshiek county lies to the north of the area, Clayton joins it on the east, Buchanan borders it on the south and Bremer and Chickasaw form its western boundary.

* Gue: History of Iowa, Vol. I, p. 188, and Vol. III, p. 844.

The eastern border of the county is only about twenty-two miles west of the Mississippi river, and the northern border thirty miles south from the state line. Fayette county forms a rectangle thirty miles in length from north to south, and twenty-four miles in width. It comprises twenty government townships—townships 91 to 95 north of the base line, and ranges VII to X west of the fifth principal meridian. It has an area of 720 square miles.

In the number of geological formations exposed, and in the favorable manner in which the relations of the different strata are exhibited, this region is surpassed by but few of the counties of the state. No other area of like size presents a richer variety of topographic forms expressed in widely extending prairies; forest mantled hills; deep, picturesque ravines which are bordered by high bluffs and precipitous ledges of limestone; and charming streams which are fed by scores of never failing springs.

EARLIER GEOLOGICAL WORK.

As early as 1839 Dr. D. D. Owen* collected and described a few fossils from the rocks exposed at various points along the Turkey river in or near Fayette county. In his report he calls attention to the symmetrical form of the hills which border the larger streams of the area. He also discussed in a general way some of the geological formations in the northeastern portion of the county.

In Hall's report on the Geology of Iowa† published in 1858, Prof. J. D. Whitney devotes three or four pages to a general discussion of the geology of the area under consideration. Mr. Whitney considered the Niagara limestone to have a much wider distribution and a much greater thickness in the county than the present studies seem to indicate. He also speaks of the Galena limestone appearing in the valley of the Turkey river throughout its entire length in the county.

*Owen: Geol. Surv. of Wisconsin, Iowa and Minnesota, pp. 74 and 577.

†Hall: Geology of Iowa, Vol. I, part I, pp. 302-305.

Fayette county is embraced within the region discussed by W J McGee in his Pleistocene History of Northeastern Iowa.* In that work several references are made to some of the topographic features, loess and drift deposits, and a few of the exposures of indurated rocks occurring within the limits of Fayette county.

In reducing the gradient of their road bed in 1896 the Chicago Great Western railway company made a deep cut a short distance southeast of the town of Oelwein. In this excavation an exceedingly instructive section of the Pleistocene deposits was exposed. In a paper before the Iowa Academy of Sciences in 1896 Mr. G. E. Finch† described the drift materials exposed at this place. The same drift exposure has been discussed by Prof. S. W. Beyer‡ who gave a section of the beds and referred the lower till, there to be seen, to the pre-Kansan age. At the meeting of the Iowa Academy of Sciences that same year Prof. T. H. Macbride§ described the Pre-Kansan Peat Bed that was exposed in the above mentioned cut, and discussed the conditions that must have obtained at the time the deposit was accumulating.

In a paper treating of The Galena and Maquoketa Series, Mr. F. W. Sardeson‖ refers to a number of places in Fayette county where there can be seen exposures of different beds that he mentions in his classification of the Maquoketa deposits.

Prof. G. E. Finch** has described an old terrace formation along the valley of the Turkey river in Fayette county. The same writer†† has discussed the significance of the position of individuals of *Nileus vigilans* that were found in strata near Elgin, in the county under consideration.

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* McGee: Eleventh Ann. Rept. U. S. Geol. Surv., Washington, 1890.

† Finch: Proceedings Iowa Academy of Sciences, Vol. IV, p. 54, *et seq.*, 1897.

‡ Beyer: Ibid., p. 58 *et seq.*

§ Macbride: Ibid., p. 63 *et seq.*

‖ Sardeson: American Geologist, Vol. XIX, pp. 80-83, 1897.

** Finch: Proceedings Iowa Acad. Sci., Vol. VIII, p. 204, *et seq* 1901.

†† Finch: Ibid., Vol. XI, pp. 179-191, 1904.

PHYSIOGRAPHY.

TOPOGRAPHY.

Over all the western and southern portions of Fayette county the surface is generally level or but gently undulating, except in close proximity to the larger streams. The topography of the northeastern part of the area is in striking contrast to that of the prairie portion. In this more hilly region the valleys and uplands are often separated by a difference in altitude of 300 to 400 feet. In many places high ramparts of Niagara limestone bound the valleys of the larger streams, and look down upon the tumultuous waters which flow in feverish haste past ancient crags, and weathered peaks, and gently rounded bluffs whose materials have been wasted through geologic ages by the slow processes of denudation.

The topography of each of the above mentioned areas, like that over the greater portion of our state, finds its explanation in the length of time since the leveling ice plow last withdrew from each particular region, and consequently in the length of time during which the streams of these areas have been uninterruptedly carving their channels.

It is possible that the extremely uneven surface of the northeastern portion of the area is partially due to the fact that only the edge of the Kansan glacier overspread the region. This marginal portion of the ice sheet was much less effective as an eroding or leveling agent than the thicker mass further from the periphery. On this account the preglacial topography here was not greatly obscured by the Kansan ice sheet. After the withdrawal of the ice the streams continued to follow the preglacial courses, and as a result of the but slightly interrupted erosion the action of the streams is much more marked here than over the general surface of the Kansan drift plain.

THE IOWAN-KANSAN BORDER.

In Fayette county, as in other counties that are crossed by the border of the Iowan drift, the margin of this drift area is

fringed by a line of irregular hills which are so deeply loess covered that their summits reach an altitude considerably greater than that of the general surface on either side.

This sinuous line of hills that marks the border of the Iowan drift plain enters Fayette county, from Clayton, near the northeast corner of section 36 of Fairfield township. It extends in a northwesterly direction up to about the middle of section 25, thence west for one mile, and continues with a trend a little north of west, about one-half mile north of the town of Arlington. It crosses the north end of section 27, the extreme southwest corner of section 22, the south end of section 21, and passes up to near the middle of section 20. It here bends more nearly northward across the southwest corner of section 17, and up to one-fourth of a mile east of the middle of section 18. It then swings to the northeast for one-half mile after which it bears once more to the northwest across the south half of section 7 of Fairfield township, and the north half of section 12 of Smithfield township, and on to the middle of the north line of section 11. Here it once more bends to the northeast, reaching the middle of the east line of section 2. Thence continuing towards the northwest it enters Westfield township about the middle of the south side of section 35. After crossing the southwest ¼ of the latter section and the north half of section 34, it loops to the northward across the extreme southwest corner of section 27 and the southeast corner of section 28, invading the corporate limits of the town of Fayette. It swings down a short distance below the north line of section 33 and again bears to the northwest, passing to the west and north of Fayette at a distance of one-half to one and one-half miles. It crosses the extreme southwest corner of section 28, the southeast corner of section 29 and the northwest corner of section 32. It again bears northward across the northern part of section 31 and the west side of section 30, whence it swings towards the east across the southeast corner of section 19, the middle of section 20 and on to near the northeast corner of section 21. It continues with many meanders in a general northerly direction for some six or seven miles. It takes a northwesterly trend across the southwest corner of section 16 and the northeast corner of section 17.

It then bears in a northeasterly direction across the extreme southeast corner of section 8 and on to the middle of the east half of section 9. From this point it swings again to the northwest and continues up to about the middle of the east half of section 5. Here it swings towards the northeast up to the extreme northeast corner of section 4. It then bears towards the northwest to near the middle of the west half of section 33 of Union township. Swinging eastward it continues up to the northeast corner of section 33 and across the north end of section 34. Bearing more to the northward it passes across the northwest corner of section 35, the southwest corner of section 26 and on to a short distance north of the middle of the west half of section 27. From this point it bears eastward to the northeast corner of section 27, and thence continues towards the northwest diagonally across the southwest ¼ of section 22, the northeast part of section 21, and the southwest ¼ of section 16, crossing the southeast corner of the town of West Union.

From a point near the middle of the east line of section 17 the hills extend southward for one mile, and thence continue towards the northwest, about one-half mile to the west of the city limits. This border crosses section 20 and the extreme southwest corner of section 17. It cuts diagonally across section 18 and enters Windsor township a little north of the southeast corner of section 12. It continues toward the northwest across section 12, the north part of section 11, the northeast corner of section 10, the southwest corner of section 3, across section 4, and enters Auburn township a short distance west of the southeast corner of section 32. These moraine-like hills continue up to the middle of the northwest ¼ of section 32, where they swing towards the southwest, reaching the southwest corner of section 31. Thence they bear a little west of north to a point a short distance north of the middle of section 25 of Eden township. They then trend due east for one mile and then north one-half mile, whence, after a slight curve to the south, they continue towards the northeast up to near the middle of the west side of section 21 of the township of Auburn. With an eastward trend having a gentle southward curve they cross the south half of section 21 and continue

nearly to the east side of section 22, within one mile of Auburn Mills. At this point they swing northward to the northeast corner of the same section 22. They continue to the northeast up to the middle of section 14, thence bear towards the northwest to the extreme northwest corner of section 14, across the south side of sections 10 and 9 and up to within a short distance east of the middle of the west side of section 8. Here they swing once more to the northeast, passing through the town of Saint Lucas, across the southeast corner of section 5, the northwest corner of section 4, and leave Fayette county about one-fourth of a mile east of the northwest corner of section 4 of Auburn township.

THE AREA OF IOWAN DRIFT.

The area lying to the south and west of the line of moraine-like hills traced above was covered by the Iowan glacier. Over all of Putnam and Scott townships, and the greater portion of Jefferson, Oran, Fremont, Harlan and Center, the south part of Fairfield, and all of Smithfield, with the exception of a small area in the northeast corner, the topography is that of a gently rolling, slightly dissected drift plain. This undulating prairie surface is interrupted only where marshy, concave depressions, which mark the initial drainage courses, meander with many devious curves and finally deliver their waters to some larger stream, which occupies a definite yet shallow channel. The bottoms of these trough-like depressions are only fifteen to thirty feet below the summits of the ridges between which they lie, and their gently sloping sides merge insensibly into the gentle swells of the upland plain.

To these major depressions numerous grassy swales owe allegiance, and their tortuous, digitating lobes separate the otherwise level prairie into a series of broad, sinuous swells which alternate with shallow, grassy sloughs.

In Oran and Fremont townships the Wapsipinicon river flows in a broad valley one and one-half to two miles in width. Ponds and marshes, some of them of large extent, are not infrequent over its flood plain. The channel is bounded by

low banks eighteen to twenty feet in height which are generally composed of moderately coarse gravel, and this is often covered with a mantle of sand. At a few places in Oran township low ledges of indurated rock appear in the banks of the streams, but such exposures are limited to the south part of the township.

In the east half of Harlan township, and the south part of Center, the generally level surface is broken by the erosion of the Volga river and its principal branches. The hills adjacent to these streams are low and the inclinations are gentle.

In the town of Maynard, and for a distance of about one mile both to the north and the south of the city limits, ledges of Devonian limestone are encountered at frequent intervals along the banks that border the river. Deposits of water laid gravels bound the bed of the stream as it courses through sections 10 and 2 of Center township. From the north side of section 2 of this township, down to where it leaves the county, the river is confined between walls of limestone or bluffs of shale.

In the northeast corner of Eden township, the central and northwestern portion of Auburn, and practically the whole of the townships of Banks and Bethel, the level surface resembles that of the southern townships described above. The topography of the southwest corner of Union township, the northwest portion of Westfield, and all but the extreme northeast corner of Windsor and the southeast portion of Center, is also that of a recent drift plain scarcely modified at all by stream erosion.

Contiguous to Crane creek and Little Turkey river, in Eden township, the surface is quite broken. These streams occupy broad, shallow valleys whose bordering banks are prevailingly of gravel. Erosion is limited to a narrow area adjacent to the major channels.

Remnants of a bluff that bordered a pre-Iowan stream are left as a series of disconnected mounds which crown the west bank of a branch of the Volga river in sections 20, 17 and 18 of Center township. A number of paha-like hills that appear to be the remains of pre-Iowan elevations occur over the Iowan plain between Arlington and Fayette. Another such ridge extends across the north side of section 14, in Windsor township.

These ridges stand at a distance of one-half to one and one-half miles from the Iowan margin, and their long axes are usually somewhat parallel with the Iowan border. The hills are forty to sixty feet in height and are usually loess covered. The cores of some of them are composed largely of gravel, while those of others are made up of Kansan drift materials. They doubtless represent more or less subdued hills which for some reason or other escaped complete destruction when the Iowan glacier overspread the region.

Notwithstanding the fact that over the area of Iowan drift in Fayette county the surface changes are so gradual and the slopes are so gentle that there appears to be but little relief to the landscape, the region presents a maximum topographic relief of nearly three hundred feet. The bed of Otter creek, south of Oelwein is a little less than 1,000 feet above the level of the sea. That of the Wapsipinicon river, in Oran township, is of about the same altitude. The inconspicuous divide that separates these streams reaches a height of 1,100 feet. In the north central portion of Scott township, and the northwest corner of Putnam, the watershed between the Volga river and the branches of the Maquoketa rises 1,200 feet above the sea. In the eastern portion of Smithfield township the uplands have an altitude somewhat greater than 1,200 feet. Near the northwest corner of Harlan township, between the headwaters of Otter creek and those of the Volga river, the divide has an elevation of about one thousand two hundred feet. In Bethel township, west of Hawkeye, the uplands rise to a height of 1,220 feet, while in Windsor township the height of land between the basins of the Volga and the Turkey rivers reaches a maximum altitude of 1,280 feet.

Over all of the western and southern portions of the county granite bowlders are very numerous. They are usually found along the sloughs and on the flanks of the slopes. Many of these are so large that they constitute conspicuous topographic features, as in section 18 of Jefferson and section 19 of Oran township. Within a few miles of the Iowan border, the bowlders are not less abundant, but for some reason they become

much smaller in size so that their effect on the landscape is much less marked.

Near the southwest corner of section 26, Smithfield township, there are a number of low mounds that are probably the work of some prehistoric inhabitants of the region.

THE AREA OF KANSAN DRIFT.

All of that portion of Fayette county lying to the east and north of the Iowan border belongs to the Kansan drift plain. The drift materials here are, for the most part, covered deeply with loess and the surface is quite thoroughly dissected. The mantle of Kansan drift that underlies the loess is very thin. In many places it appears to have been entirely removed by the agents of denudation prior to the laying down of the loess. This area is, in fact, a part of a broad plateau that has a general altitude of about one thousand two hundred feet. The table land is determined by the resistant layers of Niagara limestone which here immediately underlie the superficial materials.

The topography of this region has been developed through the erosion of the streams which, during long geological ages, have cut through the floor of Niagara limestone and have carved their channels deeply into the underlying beds. This broad plateau has been profoundly trenched by the waters of the Turkey river and of its chief affluents, the Little Turkey and Otter creek, and, further south, by the Volga river.

In sections 30 and 31 of Westfield township the Volga river flows in a channel one-half mile in width. In some places, as at Eagle Point, the valley is bordered by cliffs of Devonian limestone sixty to seventy feet in height. See figure 33. Between Fayette and Albany the river is confined in rather a narrow channel between precipitous ledges of Niagara limestone. From this point onward in its course through the county the shales of the Maquoketa stage appear in the banks and become manifest in the topography. At Lima the channel has expanded to nearly one mile in width. The shales that appear in the immediate foot hills have a gentle slope for a distance of several

rods on either side of the flood plain, and to a height of fifty or sixty feet. Above this line the Niagara escarpment rises sheer fifty feet more. From the top of this ledge the incline is rather gradual to the level of the uplands above. Continuing down the river its channel grows constantly wider, the gentle gradient of the Maquoketa shales rises constantly higher in the bound-

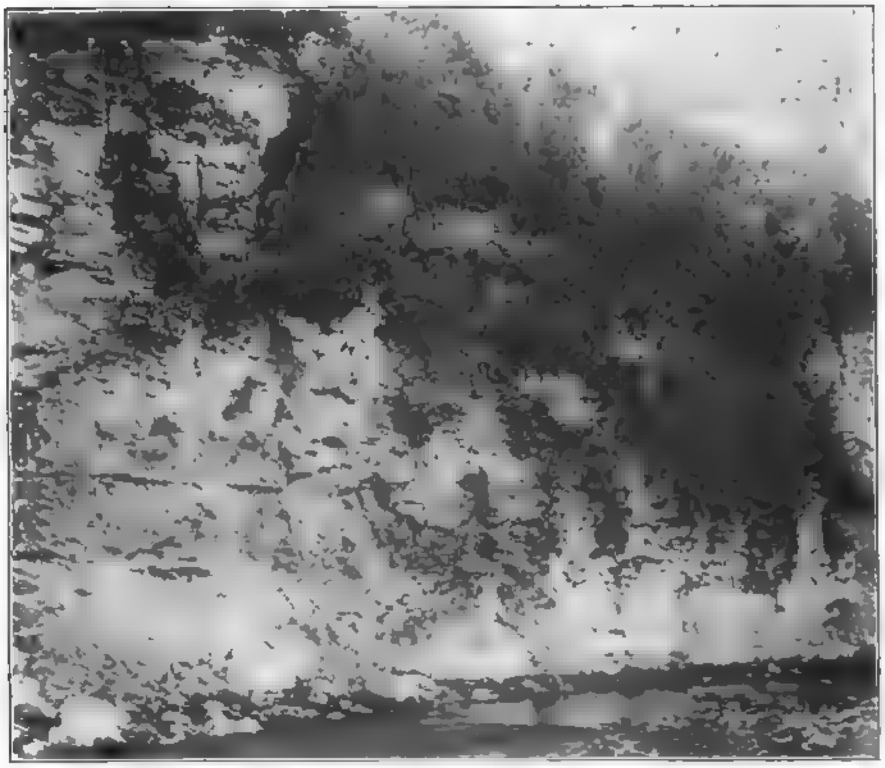

FIG. 83. Bluff of Devonian limestone in the south bank of the Volga river, near Eagle Point; one and one-half miles west of Fayette. The level of the water is about ten feet above the base of the Devonian.

ing bluffs, and the Niagara escarpment gradually recedes on either side of the valley. Below Wadena the flood plain is one and one-half miles in width. In the river banks the gentle erosion curves of the shale are conspicuous to a height of nearly one hundred feet and for a distance of one-half mile back on either side of the channel.

The shale at the upper part of the Maquoketa deposits yields much more rapidly to the agents of erosion than do the overlying layers of limestone. As a result there is left in many places a narrow shelf of the limestone somewhat overhanging a bed of shale. As portions of the Niagara materials become unsupported, large masses are detached from the parent ledge and creep slowly downward towards the river flat, making ever wider the gorge of the stream. Such talus blocks are prominent features of the landscape over the gently inclined surface of the Maquoketa shales, often having temporarily come to rest many feet below the mass from which they were separated. Above the Maquoketa shale interrupted ramparts of Niagara limestone face each other across the valley of the river, which is here nearly two miles in width. From the top of this scarp the slope rises to a height of 300 feet above the level of the water.

Trees of hard maple thrive well on the Niagara crest and over the adjacent slopes. During the autumn months the rich crimson and gold of the leaves of the maple and sumach, mellowed by the softer hues of the oak and the aspen, lend an indescribable charm to the picturesque crags and weathered towers and peaks that crown the river bluffs.

The waters of Otter creek, between West Union and Elgin, have cut a gorge to a maximum depth of about three hundred and thirty feet. From about three miles west of the town of Brainard to the confluence of Otter creek with the Turkey river, there have been developed topographic forms which resemble those seen along the Volga river in the eastern portion of the county. Passing down the stream east of West Union the gorge gradually widens and the gentle erosion curves of the Upper Maquoketa shales rise constantly higher in the banks.

The Maquoketa beds flank either side of the flood plain to a maximum height of about two hundred feet and for a maximum distance of about three-fourths of a mile from the bed of the stream. The precipitous and somewhat interrupted scarp of Niagara limestone crowns the bluffs on either side of the valley.

The tributaries of this creek are usually rather short, with a very steep gradient. They have formed conspicuous alluvial fans composed largely of blocks of Niagara limestone which have been brought down from the steeper portions of the channel and stranded where the velocity of the stream was checked by the change to a more gradual slope. Along the larger tributaries the landscape presents features very similar to those that are encountered in the channels of the streams to which they render tribute.

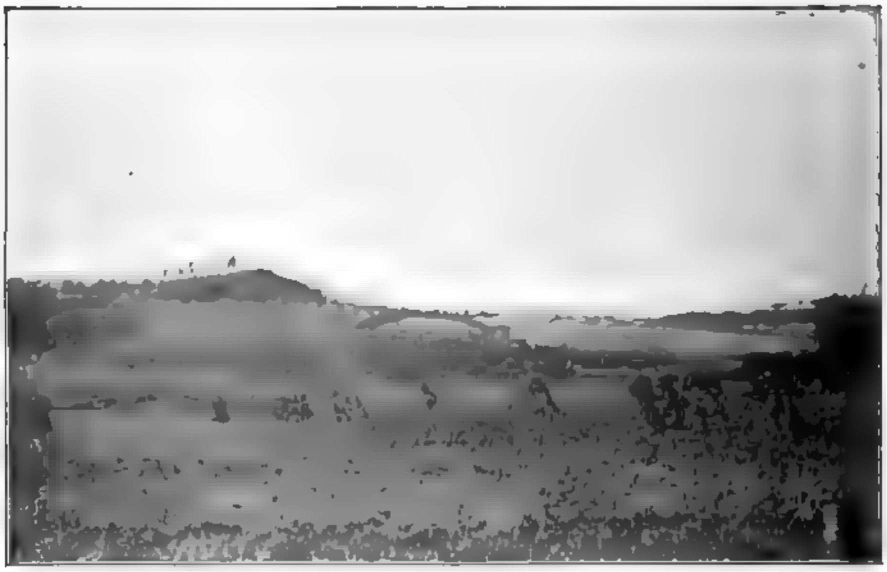

FIG. 84. View showing the gentle erosion curves of the Maquoketa shales and the scarp of Niagara crowning the slope. Along Otter creek in Pleasant Valley township.

The divide between the Volga river and Otter creek, and that between Otter creek and the Turkey river, are covered with a thick mantle of loess. Here, as elsewhere in the county, this material conforms in general to the inequalities of the preloessial surface. The regions have suffered extensive erosion and are thoroughly trenched by the lines of drainage. The topographic relief of these areas is unusually great owing to the proximity of the gorges occupied by the major streams.

The valley of the Turkey river is an excellent example of an old stream channel that has been developed through long continued ages of erosion. Throughout its course in the county the immediate banks which border the flood plain rise with a fairly abrupt slope to a height of from seventy-five to one hundred and fifty feet above the water. This bluff or terrace is determined by the presence of the indurated, cherty layers of the Middle Maquoketa deposits.

FIG. 35. View showing topography of the area over which the Upper Maquoketa shale underlies the superficial materials. Northeast ¼ of section 28, Clermont township.

With the exception of a small area in sections 2 and 3 of Auburn township, on the west, and a still more narrow strip about one mile in width bordering Clayton county, the region lying to the north of the river is a much trenched and thoroughly dissected plain. The surface is quite deeply loess covered. The tributaries of the second and the third order have carved deep channels in the comparatively soft shales of the Upper Maquoketa which immediately underlie the Pleistocene deposits over all of this area. The character of the topography of this portion of the county lying to the north of the Turkey river is shown in figure 35. The surface features are not

greatly unlike those of the typical loess-Kansan areas in other parts of the state, with the exception that here the superficial materials are underlain with nonresistant beds which have permitted even the smaller streams to develop more conspicuous trenches than is usual where the materials are more indurated.

On the south side of the river, for a distance of from one-half to one and one-half miles, the surface rises with a rather gradual slope to a height of about one hundred feet above the top of the terrace that bounds the flood plain. Over this region the loess is deep and the streams have developed topographic features similar to those encountered over the area north of the river. This gently sloping, much dissected strip, which borders the river on the south, is crowned by the more or less interrupted escarpment of Niagara limestone thirty to sixty feet in height. The resistant Niagara bed determines the skyline over all of that portion of the county lying to the east of Saint Lucas, Auburn Mills and West Union, and to the north of the town of Arlington and the Iowan drift border.

A double rampart or terrace—the upper formed by the Niagara and the lower by the indurated layers of the Middle Maquoketa, the two being separated by the softer erosion curves of the Upper Maquoketa beds—is a characteristic feature of the landscape, not only bordering the south side of the Turkey river and along all of the larger streams which render tribute thereto from the south, but also in the extreme eastern and the extreme western portions of the area north of the river where outliers of Niagara limestone cap the highest knobs.

This double scarp is very conspicuous in the bluffs that border the Little Turkey river between Auburn Mills and Eldorado. Further west in the southwest ¼ of section 30, Auburn township, the low banks of the Little Turkey are composed of Niagara limestone. Large talus blocks of this material are abundant along the foothills but the bluffs are not conspicuously high. Indeed, the Niagara here does not form prominent topographic features until quite a depth of the underlying shale is cut through by the streams, at which time the resistant cap of Niagara stands out in strong relief. On this account the

materials of the Niagara formation determine topographic forms to an extent out of all proportion to the thickness of the beds.

Flood Plains and River Terraces.—In the vicinity of the town of Fayette and further eastward, from the little village of Albany to the Fayette-Clayton county line, the Volga river flows in a broad flood plain from one-half mile to more than one mile in width. Just north of Albany, where the river is joined by a creek from the north, the river swamp expands into a wide plain which embraces about six hundred acres. Between Brainard and Elgin the waters of Otter creek have developed a river swamp from one-fourth to one-half mile in width.

The alluvial flats that border the above mentioned streams are insignificant, however, when compared with the flood plain that has been developed by the waters of the Turkey river. The latter stream meanders in a river marsh which has an average width of more than one mile. At Eldorado, where the river receives the water of the Little Turkey, the streams have carved out a broad amphitheater nearly two miles in diameter. Another such expansion of the flood plain has been formed at Dover Mills where the width is not much less than that at Eldorado.

Within the Iowan drift plain the Little Turkey and the Wapsipinicon rivers occupy broad depressions that are not true flood plains. These channels are remnants of preglacial valleys that were successively almost filled with detritus during the invasions of the Kansan and the Iowan glaciers.

Remnants of an old terrace eighteen to twenty feet in height are encountered at several points along the Turkey river. In the expansion of the flood plain at Eldorado these gravels cover an area of more than three hundred acres just east of the business portion of the town. In the angle of the valley west of the village the terrace is also conspicuous.

About two and one-half miles east of Eldorado, in the vicinity of the Huntsinger bridge, this old terrace is continuously exposed for a distance of nearly one-half mile. At this place the top is twenty feet above the level of the present flood plain. See figure 36. Near Dover Mills remnants of the terrace again

become conspicuous. The greater portion of the town of Clermont stands upon this gravel train. The gravels of the pit worked by the Chicago, Rock Island & Pacific Railway Company near Clermont are a part of this old fluvial deposit. Beds of gravel, somewhat modified by the more recent action of wind and water, are encountered along the river between Clermont and Elgin. The cemetery at Elgin is located upon a bench of this material, and the wagon road follows on such a terrace for some distance east of Elgin, to near the county line.

FIG. 86. View of the gravel terrace along the Turkey river, near the old Huntsinger bridge, two and one-half miles east of Eldorado. The gravel bench is twenty feet in height. The top of the very rusty, iron-stained zone appears a little below the middle.

In the vicinity of Waucoma these coarse, water-laid materials form a bench fifteen to eighteen feet in height, bordering the channel of the Little Turkey river. They are also encountered at the bridge near the south side of section 30 of Auburn township, and at other points along this stream.

To a height of a few feet in the lower part of the terrace the materials are highly ferruginous and profoundly oxidized, as shown in figure 36. The gravels in the upper portion are more fresh and but slightly stained with iron.

All of the facts seem to indicate that during the melting of the ice of the Kansan glacier the Turkey river was the line of discharge of a much larger volume of water than it carries at present. During this period of high water and excessive transportation, the river deposited a thick bed of gravel over the surface of the pre-Kansan flood plain. During the long interval between the Kansan and the Iowan ages the meanders of the river carved out this bed of gravel and lowered the flood plain to nearly its present level, leaving only disconnected patches of the former stream deposit in the form of a low terrace along the sides of its channel. Once again, when the Iowan ice was melting, there was a long period when the stream was flooded. During this interval a large river poured its torrents along this channel and formed wide embayments at the mouths of the tributary streams. At this time another blanket of river gravels was spread over the flooded plain, burying the alluvium of the bottom lands and the remnants of the Kansan terrace and building a flood plain deposit some feet higher even than that formed during the retreat of the Kansan ice.

After the melting of the Iowan ice, and the recession of the waters, the stream developed a flood plain at a new level which was determined by the mean volume of water that it has carried in recent years. Its meanders have removed all but a few scattered fragments of the materials it earlier deposited, which remnants reveal some of the chapters in the history of the changes that the stream has wrought, and in which it has had a share.

The elevation of the following places will give a general idea of the height above sea level of representative points in the county. The figures were taken from Gannett's Dictionary of Altitudes in the United States, from data furnished by the United States topographic sheets and from aneroid readings.

TABLE OF ALTITUDES.

	FEET.
Arlington	1113
Auburn	970
Brainard	919
Clermont, at station	866
Donnan	1151
Dover Mills, level of flood plain	863
Eldorado	924
Elgin	843
Fairbank	1000
Fayette	1003
Hawkeye	1173
Lima	935
Maynard	1106
Oelwein, Chicago, Rock Island & Pacific Railroad	1049
Oelwein, Chicago Great Western Railroad	1036
Postville Junction	1062
Putnam township, middle	1113
Randalia	1106
Saint Lucas	1060
Scott township, middle	1143
Smithfield township, middle	1168
Stanley	1098
Sumner	1060
Wadena	877
Waucoma	1045
Westgate	1091
West Union, Chicago, Rock Island & Pacific Railroad	1155
West Union, Chicago, Milwaukee & Saint Paul Railroad	1109

The lowest point in the county is where the channel of the Turkey river crosses the Fayette-Clayton county line at an elevation of 775 feet above the sea. The highest known point is in the northwest ¼ of section 14 of Windsor township, which reaches an altitude of 1,285 feet. The maximum topographic relief in the county is not less than 500 feet.

DRAINAGE.

The streams of Fayette county contribute to three principal drainage systems, whose master streams are the Wapsipinicon, the Maquoketa and the Turkey rivers. The main lines of discharge were outlined in preglacial times, but the cycle of erosion and the development of the respective basins were interrupted at least twice, and in some cases a third time, by the incursion of an ice sheet from the north. Each successive invasion of the ice choked the river valleys with glacial detritus, and more or less completely obliterated the channels of the smaller tributaries, and the minor inequalities of the pre-existing surface.

The Wapsipinicon River.—The Wapsipinicon river receives the run off from an area of about one hundred and sixty square miles in the southwest part of Fayette county. Its tributaries drain practically the whole of Jefferson, Oran and Fremont townships, and the west half of Banks, Harlan and Scott. The chief streams of this system in the county are the Little Wapsipinicon river and Otter creek. The former flows in a general southerly direction for a distance of about fifteen miles, in the south part of the western portion of the county.

The headwaters of the Otter creek that renders tribute to the Wapsipinicon river drain the larger portion of Harlan and Jefferson townships. These small streams, like the ultimate branches of all of the streams that gather water for the Wapsipinicon river, are fed by springs which issue in the form of marshes over the Iowan drift plain. They follow shallow depressions that were formed by the irregular heaping of the drift materials as the Iowan ice melted. Channels of erosion have been but slightly developed over this area, except in close proximity to the larger streams. Even these larger valleys owe their present features almost as much to the deposition of the drift in a preglacial channel as to the normal processes of water action.

The Maquoketa River.—Small streams which owe allegiance to the Maquoketa river drain about fifty square miles of the townships of Putnam and Scott. These small creeks are typical Iowan water courses. Like the branches which constitute the

headwaters of Otter creek and the Little Wapsipinicon river, they rise in marshy swales and follow swamp-like depressions which wind around the swells with many tortuous meanders and finally discharge their waters into another series of marshes whose channels are scarcely more distinct than those whose waters they receive.

The Turkey River.—The Turkey river includes in its basin nearly three-fourths of the surface of Fayette county. Its water flows in an old valley which, with an exceedingly sinuous course, crosses the northeast corner of Auburn township, the middle portion of Dover, the southwest corner of the township of Clermont and the northeast corner of Pleasant Valley.

The largest tributaries of the Turkey river in the region under consideration are the Little Turkey river and Otter creek. The former stream enters the county near the northeast corner of section 5 of Eden township. It follows a southeasterly course down to the northwest corner of section 31 of Auburn township. It then bears eastward to the village of Auburn, whence it trends towards the northeast for a few miles, its waters meeting those of the Turkey river near the town of Eldorado, in Dover township.

The Otter creek that owes allegiance to Turkey river takes its rise in the springs and swales of the Iowan plain near the east side of Windsor township. It follows a generally eastward course for a dozen miles, draining the greater portion of Union and the southern part of Pleasant Valley township, and joins the river near the town of Elgin. Numerous other streams of smaller size pay tribute to the Turkey river both from the north and from the south. Those from the north, which have worked in the beds of the Maquoketa shale, have developed longer channels and a more widely branching series of tributaries than those from the south, whose waters have acted upon the resistant ledges of the Niagara limestone.

Crane Creek.—Crane creek is the principal affluent of the Little Turkey river in Fayette county. It flows eastward across the southern portion of Eden township, and joins its major stream near the northwest corner of section 31 of Auburn township. It drains the north half of Bethel township and the south and west portions of Eden.

again, only to be as often interrupted by some slight shifting of the level of the land. There is every reason to suppose that the region was denuded of many hundreds of feet of strata that once overlay the uppermost Devonian rocks that now appear in the county.

The records of this immensely long period, that have here been preserved, are exceedingly slight when compared with the great length of the time. They consist of deep gorges and wide valleys that were carved by the streams out of the indurated beds. Some of these channels have since become partially filled with drift and many of them are completely buried beneath the mantle of superficial materials. Even over the deeply drift-covered portion of the area, where the surface is comparatively level, well borings and artificial excavations reveal the exceedingly rugged character of the surface over which the mantle of glacial detritus was spread.

The Pleistocene period is represented in Fayette county by three different sheets of drift, together with beds of loess and deposits of gravel, sand, and alluvium. The respective till sheets were deposited during the invasion of the pre-Kansan, the Kansan and the Iowan glaciers.

The successive stages of glaciation were separated by a long period of temperate climatic conditions during which the surface of the land was mantled with vegetation and peopled with animal life very much as it was before the natural faunal and floral relations of recent times were disturbed by the advent of civilized man.

The following table shows the relations of the different geological formations that are known to be exposed in the county:

Ordovician System.

GALENA-TRENTON STAGE.

The assemblage of strata in Iowa that are included in the Galena-Trenton stage is bounded below by the sandstone formation known as the Saint Peter, and above by the beds of shale and shaly limestones which constitute the Maquoketa stage. The deposits of the Galena-Trenton were originally distributed between two stages, the Trenton and the Galena. The lower group of strata, in which limestones and shales predominate, was called the Trenton. The upper beds, which further south are prevailingly dolomitic, were designated as the Galena.

Professor Calvin * has shown that these two groups of strata constitute one geological unit; that there is no stratigraphic or biologic line of separation between them. In certain places the materials have suffered local alteration which resulted in the dolomitization of the upper beds to a variable depth. The term Galena-Trenton is now applied to the entire aggregate of layers which are embraced between the limits mentioned above.

It will be observed from the foregoing table that the oldest rocks exposed in Fayette county belong to the Galena-Trenton stage. The materials are quite pure limestones, light gray in color, fairly fine-grained in texture, and very hard. The fragments break with a rough fracture and the weathered surfaces present a characteristic chipped and hackled appearance. The ledges are cut into rhomboidal blocks of variable size by numerous joints. The dolomite phase that is developed in the rocks near the top of this stage in Dubuque county is entirely wanting in our area.

An aggregate thickness of about thirty feet of the rocks of this stage is all that is exposed in the county. Outcrops appear at intervals to a height of ten to fifteen feet above low water in the banks of the Turkey river, from a point some distance above Dover Mills down to a short distance below the town of Clermont. Excellent exposures are encountered in the lower

* Calvin: Iowa Geol. Surv., Vol. X, pp. 406 *et seq.*, Des Moines.

TABLE OF FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium and loess.
		Glacial.	Iowan.	
			Yarmouth.	
			Kansan.	
			Aftonian.	
			Pre-Kansan.	
Paleozoic.	Devonian.	Meso-Devonian.	Cedar Valley.	
			Wapsipinicon.	Upper Davenport.
				Lower Davenport.
	Silurian.	Niagara.	Delaware.	
	Ordovician.	Trenton.	Maquoketa.	Upper Maquoketa.
				Middle Maquoketa.
				Lower Maquoketa.
			Galena-Trenton	

Ordovician System.

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* Calvin: Iowa Geol. Surv., Vol. X, pp. 406 *et seq.*, Des Moines.

portion of the channels of many of the streams that render tribute to the Turkey river between the points above mentioned. The rocks can be well studied in the post-glacial gorge near Dover Mills. They can be seen in the east bank of the river in sections 32 and 29 of Clermont township. They are well exposed along the bed and in the banks of a small creek that joins the Turkey river from the north, in section 28. They border the river for some rods both above and below the mill-dam at Clermont, and they appear in the banks of a dry run where it enters the corporate limits of the town of Clermont, near the northwest corner. At the latter place, where the stream is crossed by a wagon bridge, the upper layers of the rocks of this stage are well exposed.

Usually the planes of sedimentation can scarcely be distinguished in the weathered ledges, but along unweathered joint planes the materials appear to be disposed in quite regular layers which vary from four inches to more than one foot in thickness.

In a zone about fifteen feet below the top of the Galena-Trenton deposits there occur very numerous individuals of *Murchisonia major* Hall and *Fusispira ventricosa* Meek and Worthen. Associated with these there are found in lesser numbers Lophospira sp., *Trochonema umbilicatum* Hall. *T. robbinsi* Ulrich and Scofield, and *Fusispira nobilis* U. and S. From the rocks lying between this horizon and the top of the Trenton stage were collected *Zittelella lobata* U. and E., a second species of sponge that was undetermined, *Receptaculites oweni* Hall, *Ischadites iowensis* Owen, *Lingula iowensis* Owen, *Rafinesquina minnesotensis* N. H. Winchell, *Leptaena rhomboidalis* Wilckens, *Lophospira fillmorensis*? U. and S., Orthoceras sp. and an undetermined species of Illaenus. Near the top the materials of this stage grade up into a bed about nine feet in thickness, made up of layers of gray, crinoidal limestone which alternate with bands of calcareous shale. Both the shale and the indurated layers are from three to six inches in thickness; and both contain numerous fossils, among which were found *Streptelasma corniculum* Hall, *Rafinesquina alternata* Conrad, *R. deltoidea* Conrad, *Plectambonites sericea* Sowerby, *Strophomena*

incurvata Shepard, *Orthis* (*Dalmanella*) *testudinaria* Dalman, and a variety of this species of Orthis. The above bed is well exposed in a railroad cut a short distance northwest of Clermont. These layers can also be seen in the banks of a small ravine that discharges from the east into the lower post-glacial gorge, in section 24 of Dover township. They represent the transition from the Galena-Trenton to the Maquoketa deposits.

MAQUOKETA STAGE.

The strata of the Maquoketa stage constitute the uppermost deposits of the Ordovician system found in the state. The name Maquoketa was applied to the rocks of this stage by Dr. Charles A. White from the fact that these deposits are well developed along the Little Maquoketa river in Dubuque county. The term is synonymous with the Hudson River Shales* as used by Hall†, in his report on the Geology of Iowa. Dr. D. D. Owen‡ did not differentiate this group of strata when he discussed the geology of eastern Iowa, but included them in the deposits of the Upper Magnesian limestone.

In Fayette county the Maquoketa materials immediately underlie the Pleistocene deposits over nearly the whole of the area north of the Turkey river. They border that stream on the south over a strip one-fourth to one and one-half miles in width. They are seen in the bed of Otter creek, and appear in its banks to a constantly increasing height from the point where they are first encountered, about one and one-half miles east, and one-half mile south of West Union, to the junction of this creek with the Turkey river. In like manner the Maquoketa shale fringes the channel of the Little Turkey river from Auburn Mills to Eldorado. Near the bridge across the Little Turkey river, about the middle of the south side of section 30 of Auburn township, the Maquoketa shale appears in the north bank of the river to the height of nearly six feet above low water. As far as known this point is the most westerly exposure of the Maquoketa deposits that occurs in the county.

* White: Geology of Iowa, Vol. I, p. 180, *et seq.* 1870.
† Hall: Geology of Iowa, Vol. I, part 1, p. 64, *et seq.*
‡ Owen: Geology of Wisconsin, Iowa and Minnesota.

The shales of this age appear along the channel of the Volga river from a point some distance southwest of Albany to the eastern border of the county. These materials are also encountered in the banks of all of the larger tributaries of these streams between the points above mentioned.

The strata of the Maquoketa stage over this area fall naturally into three divisions. As a convenient means of referring to these divisions they will be designated respectively as the Lower, Middle, and Upper Maquoketa beds.

The basal portion of the Maquoketa beds consists of alternating layers of shale and argillaceous limestone. In the indurated layers near the bottom there occur very numerous fragments of *Isotelus maximus* Locke (*Asaphus iowensis* Owen). Towards the middle of the Lower Maquoketa beds the calcareous materials become predominant and the layers contain abundant remains of *Nileus vigilans*, and other species of trilobites. Towards the upper part of the lower Maquoketa the proportion of shale gradually increases and the deposit blends into a bed of blue colored, tenaceous clay. The maximum thickness of the Lower Maquoketa strata is about ninety-five feet.

The Middle member of the Maquoketa deposits is made up of a bed of cherty limestone which in some places is strongly magnesian. Where the materials are of limestone, they are arranged in layers three to six or eight inches in thickness. The chert masses are usually somewhat segregated along the lines of bedding, but there are also numerous concretions enclosed in the limestone of the various layers. Where the rocks are the most nearly dolomitic, as at Clermont, the chert nodules are very abundant, often appearing in conspicuous bands. The thickness of this member varies from forty to sixty feet. It impresses itself strongly upon the topography of the region over which it outcrops on account of the indurated character of the layers, and because of the fact that immediately above and below this phase the materials are of rather soft, incoherent shale.

The upper division of the Maquoketa deposits is made up of a body of quite plastic, bluish-gray shale. This bed carries numerous crystals of selenite but it is practically barren of

fossils, with the exception of a zone eight to twelve feet in thickness, near the top, where there are harder, calcareous bands intercalated between layers of shale. This member has a thickness, in some places, of not less than one hundred and twenty-five feet.

The rocks of the respective divisions of the Maquoketa stage are quite constant in their lithological characters, and quite uniformly developed over all of the area of Fayette county in which they are exposed. A continuous section of the Maquoketa beds, from the base of the *Nileus vigilans* zone to the contact of the Maquoketa with the overlying Niagara limestone, can be seen on passing up the channel of Cascade gulch, a small stream which joins the Turkey river about one mile southeast of the town of Eldorado.

A consideration of a number of exposures will make clear the characteristics of the rocks of the Maquoketa stage as a whole, as well as those that distinguish the strata of each of the three divisions.

TYPICAL EXPOSURES.

The Lower Maquoketa Division.—Just below the old milldam at Dover Mills the Trenton limestone appears in the south bank of the Turkey river to a height of eight or ten feet above the water. A few rods west from this point a small stream joins the river from the south. In walking up the bed of this stream the following succession of layers is passed over, the lowest of which is about eight feet above the top of the Trenton limestone exposed at the milldam.

		FEET.
6.	Bed of bluish colored, plastic shale, not indurated; containing the fossils *Rafinesquina alternata*, *Plectambonites sericea*, *Strophomena incurvata*, *Orthis* (*Dalmanella*) *testudinaria*, and *Rhynchotrema capax*	15
5.	Bed of yellowish colored shale, in places somewhat arenaceous, the lower portion containing fragments of yellowish, impure limestone imbedded in a matrix of shale. The following fossils are characteristic of this member: *Strophomena planumbona*, *Orthis* (*Hebertella*) *insculpta*, and *O.* (*Plectorthis*) *whitfieldi*	13

		FEET.
4.	Bed composed of alternating layers of yellowish-gray shale and of yellowish colored, impure limestone, each two to three inches in thickness; argillaceous materials predominate in the upper part. The indurated bands contain numerous nodules of chert and carry the following fossils: *Hindia parva?*, *Plectambonites sericea*, *Orthis (Dalmanella) testudinaria*, *Rhynchotrema inaequivalvis*, *Murchisonia gracilis* and two or three species of Orthoceras......	16
3.	Bed of gray limestone in layers one to three inches in thickness, with thin seams of yellowish colored shale separating the successive bands of limestone; the proportion of shale increases towards the top; the following fossils are not rare: *Nileus vigilans*, *Calymene senaria* and *Pterygometopus callicephalus*.—*Nileus vigilans* zone	15
2.	Bed consisting of layers of lean, yellowish colored, indurated shale, two to three inches in thickness, with some irregular layers of limestone and bands of chert nodules of about equal thickness with the seams of shale. Fossils rare.	18
1.	Bed made up of layers of bluish colored, fine-grained, argillaceous, limestone, three to eight inches in thickness, between which are intercalated bands of blue colored shale of about the same thickness. The indurated layers of this bed contain very numerous remains of *Isotelus maximus* and a few other fossils...............	14

The foregoing will be designated as the Dover Mills section. The entire aggregate of layers which constitute the Lower Maquoketa beds are here represented. The materials of the successive members do not change abruptly, but the ratio of the shale to the calcareous constituents increases or diminishes gradually in passing from one member to another.

The lower layers of number 1 represent the basal portion of the Maquoketa deposits. This member will be referred to as the *Isotelus maximus* horizon on account of the fact that the remains of this trilobite are exceedingly abundant in the indurated layers. So numerous are the fragments of these individuals that not infrequently a score of pygidia, glabellæ and cheeks are found on the surface of a slab two feet square. Notwithstanding the abundance of the fragments of this species,

entire individuals are exceedingly rare. Mr. A. G. Becker, of Clermont, has collected a few almost perfect specimens of this species, and he has also found associated with these, an entire individual of a related species in which the cephalon is prolonged anteriorly into a peculiar snout-like projection, somewhat similar to that of the *Asaphus extenuata* Ang.* The equivalent of the rocks of number 1 are exposed below the bridge in the roadside, near the middle of section 21, Clermont township, and also along a ravine near the wagon road about the middle of the east half of section 33. They are conspicuous in the north bank of a small creek for several rods before it joins the Turkey river, near the middle of the south side of section 3 of Pleasant Valley township. They appear in a bluff just above the wagon bridge a short distance west of the middle of section 35 of the township of Clermont. The beds at the latter place are shown in figure 38. They are here overlain by the layers of the succeeding member. These beds are also well exposed, near the wagon road, in the bed and banks of a small stream about three miles east of Elgin, a short distance beyond the Fayette-Clayton county line. In all of the above mentioned exposures the remains of the characteristic fossil, *Isotelus maximus* Locke, occur in great abundance.

A bed which corresponds with number 2 of the Dover Mills section outcrops along Otter creek within the limits of the town of Elgin. The rocks of this member here form the bed of the stream, and appear in the south bank to a height of twelve or fourteen feet, underlying the zone of *Nileus vigilans.* The wagon road passing up the hill north of Clermont has been cut through the rocks of this horizon, exposing on either side a height of about eighteen feet. These materials may also be seen near the wagon road in the southeast corner of section 12 of Pleasant Valley township, and they outcrop in the south bank of a small stream in the northeast ¼ of section 11 of the township of Clermont. The rocks of this member consist of quite hard, yellowish colored shale, in layers from one to two or three inches in thickness. The shale is in places calcareous, and in others it contains an admixture of sand. Between the bands of

* See figure 1303. Zittell's Text-Book of Palæontology. Trans. by C. R. Eastman, Vol. I, p. 630.

shale are intercalated irregular layers of limestone which carry a large number of chert nodules. The limestone layers are about equal in thickness to the bands of shale. The materials furnish but few fossils, *Lophospira quadrisulcata* U. and S., *Bellerophon bilobatus* Sowerby, Trochonema sp., fragments of two other species of gastropods, *Orthoceras bilineatum* Hall and an undetermined species of Orthoceras being all that were collected from this horizon.

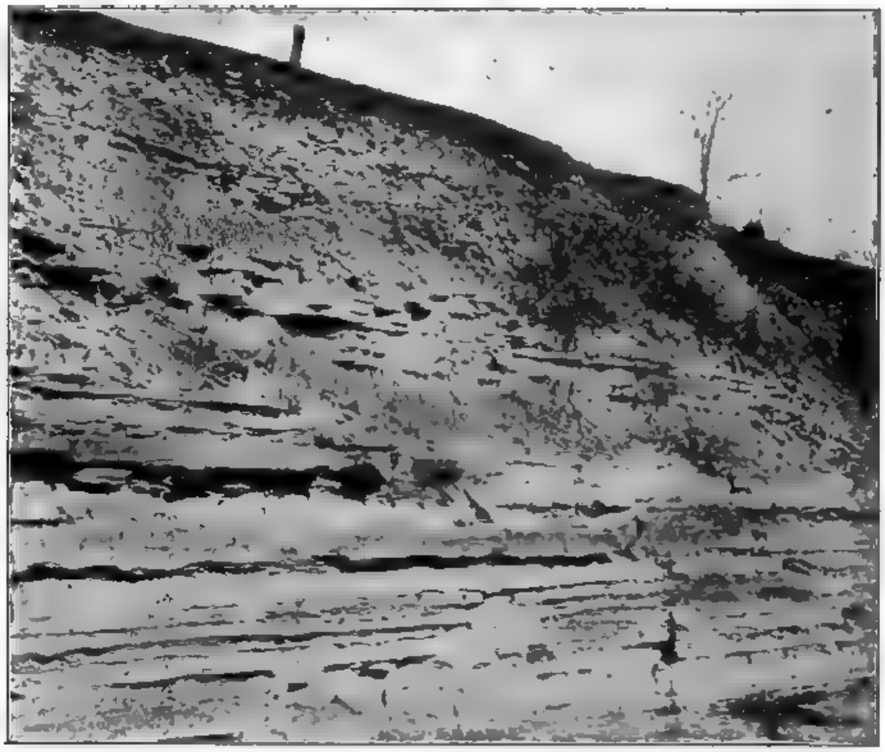

FIG 86. Beds of *Isotelus maximus* which constitute the basal deposits of the Maquoketa shales; north of the bridge in section 35, Clermont township.

Number 3 of the Dover Mills section will be known as the *Nileus vigilans* zone. The limestone layers are prevailingly thicker than the bands of shale that lie between them. The materials are gray or yellowish-gray in color and the indurated layers are quite hard. The characteristic fossil is *Nileus*

vigilans Meek and Worthen, which is most abundant near the middle of the member, but the species ranges in lesser numbers throughout the bed. Associated with the above are found several other species of trilobites, among which are *Bumastus orbicaudatus* Billings, *Ceraurus icarus* Billings, *C. pleurexanthemus* Green, *Calymene senaria* Conrad, *Pterygometopus callicephalus* Hall, and a species of Dalmanites. Besides the above trilobites the rocks of this horizon have furnished *Hindia parva* Ulrich,

FIG. [illegible]. Exposure of the Lower Maquoketa shale in the south bank of Otter creek at Elgin, Iowa. The *Nileus vigilans* zone appears in the upper part.

Rafinesquina minnesotensis N. H. Winchell, *Plectambonites sericea* Sowerby, *Strophomena fluctuosa* Billings, *Orthis* (*Dalmanella*) *testudinaria* Dalman, *O.* (*Hebertella*) *insculpta* Hall, *Rhynchotrema capax* Conrad, Trochonema sp., two undetermined species of Orthoceras and a species of Trochoceras.

[illegible]

few rods above the mill at Eldorado. They outcrop towards the top of a hill a short distance west of Postville Junction, and they are also to be seen, above the beds of number 3, in the bluff just north of the latter place. They are well exposed near the middle of the north side of section 25 of Dover township. A bed composed of the weathered materials of these layers is encountered in the roadway, about the middle of the southwest ¼ of section 4 in Dover township. At the latter exposure there were collected *Hindia parva?* Ulrich, *Rafinesquina alternata* Conrad, Leptaena sp., *Plectambonites sericea* Sowerby, *Clitambonites diversa?* Shaler, *Orthis* (*Dalmanella*) *testudinaria* Dalman, *O.* (*Hebertella*) *insculpta* Hall, *O.* (*Plectorthis*) *whitfieldi*, N. H. W., *O.* (*Plectorthis*) *plicatella* Hall, *Rhynchotrema capax* Conrad, *R. inaequivalvis* Castlenau, Bellerophon sp., and a large Orthoceras resembling *Camarooceras proteiforme* Hall.

Number 5 of the Dover Mills section consists of about fourteen feet of yellowish-gray shale which in some places is quite plastic. Crystals of selenite are not rare and, in the lower portion of the bed, there are occasional layers of impure limestone two to four inches in thickness. In a zone a short distance below the middle of this member there occurs in great abundance well preserved shells of *Orthis* (*Plectorthis*) *whitfieldi*, N. H. Winchell. Mr. Winchell* states that this species is nearly related to *Orthis kankakensis* McChesney, but that the former species is less elongated along the hinge line, is more nearly square in outline, and bears a less number of plications. The individuals, which are very abundant at this horizon in Fayette county, possess characters which ally them very closely indeed with *Orthis kankakensis* McChesney.

The layers of this member constitute the typical horizon for *Orthis* (*Plectorthis*) *whitfieldi*, although this fossil makes its earliest appearance in layers considerably lower down, and it is occasionally encountered well towards the top of this division. *Orthis* (*Hebertella*) *insculpta* Hall, also occurs the most abundantly in the layers of this member. Associated with these fossils there were found at the Dover Mills exposure *Hindia parva?* Ulrich, *Streptelasma corniculum* Hall, *Rafinesquina alternata* Conrad, *R. minnesotensis* N. H. W., *Plectambonites sericea*

*Winchell: Geol. and Nat. Hist. Surv., of Minn. Vol. III. Part I, p. 488.

Sowerby, *Strophomena fluctuosa* Billings, *Orthis* (*Dinorthis*) *subquadrata* Hall, *O.* (*Dalmanella*) *testudinaria* Dalman, and *Rhynchotrema capax* Conrad. Materials which are the equivalent of number 5 of the section appear along the road-side a short distance north of the schoolhouse, and in the banks of a small stream a few rods still further north, near the middle of the east side of section 19 of Clermont township. The layers in the east bank of this stream are in places slightly crumpled, as ap-

FIG. 40. A small fold in the Lower Maquoketa shale, at the horizon of *Orthis whitfieldi*. In a ravine a short distance west of the middle of section 19, Clermont township.

pears in figure 40, but the flexures are probably due to the creeping of the shales under the pressure from the hill above. At the latter place the *Orthis* (*Plectorthis*) *whitfieldi* horizon is well exposed. From these exposures the following fossils were collected: *Hindia parva?* Ulrich, *Rafinesquina alternata* Conrad, *R. minnesotensis* N. H. W., *Plectambonites sericea* Sowerby,

Strophomena planumbona Hall, *S. fluctuosa* Billings, *Orthis (Dinorthis) subquadrata* Hall, *O. (Dalmanella) testudinaria* Dalman, *O. (Hebertella) insculpta* Hall, *O. (Plectorthis) whitfieldi*, N. H. W., *Rhynchotrema capax* Conrad, *R. inaequivalvis* Castlenau, *Murchisonia gracilis* Hall but much less abundant than in number 4, *Bellerophon bilobatus* Hall, Trochonema sp., Conularia sp., Orthoceras sp., and *Pterygometopus callicephalus* Hall.

In passing up Cascade gulch, near Eldorado, the layers of number 5 succeed those of the fourth member of the section in their normal order, and they may also be seen overlying the layers of number 4, in the north bank of the Turkey river, a short distance above the mill in the same town. A weathered shale bed of this horizon appears in the wagon road along the south bank of the Little Turkey river about one mile west of Eldorado, near the middle of the east side of section 13, Auburn township. From this exposure a number of interesting fossils were collected, among which were *Streptelasma corniculum* Hall, an undescribed species of Streptelasma in which the septa unite at the center in such a manner as to form a columella-like elevation on the floor of the calyx, *Plectambonites sericea* Sowerby, *Strophomena planumbona* Hall, *Orthis (Dalmanella) testudinaria* Dalman, *O. (Dalmanella) hamburgensis?* Walcott, *O. (Hebertella) insculpta* Hall, *Rhynchotrema capax* Conrad, *Rhynchonella neenah* Whitfield, *Zygospira modesta* Say, *Z. recurvirostra* Hall, Ctenodonta? sp., Parastrophia sp., and Orthoceras sp.

Number 6 of the Dover Mills section represents the uppermost deposits of the Lower Maquoketa division. It consists of a bed of blue or bluish-gray, plastic shale about fifteen feet in thickness. At some points the shale carries numerous fossils, while at others not far distant it is almost barren of organic remains. This upper phase of the Lower Maquoketa deposits is well exposed in the abandoned clay pit of the Clermont Brick and Tile Company, in the hill north of Clermont. At this place the shale bed is overlain by the indurated, chert-bearing layers of the Middle Maquoketa division. The pit from which the clay for the above mentioned plant is taken at present is worked in the same horizon, a short distance below the top of the member. At none of these exposures were fossils abundant.

Just south of a small wagon bridge near the line between sections 19 and 20 of Clermont township, the hard, cherty layers of the Middle Maquoketa division can be seen overlying a bed of tenaceous, blue colored shale which corresponds with number 6 of the section at Dover Mills. The transition from the shale to the limestone is abrupt, as is usually the case wherever the contact between these two divisions is seen. The shale at this place is about fourteen feet in thickness and carries the following fossils: Crania? sp., *Rafinesquina minnesotensis* N. H. Winchell, *R. alternata* Conrad, *Plectambonites sericea* Sowerby, *Strophomena fluctuosa* Billings, *Orthis* (*Dalmanella*) *testudinaria* Dalman, *O.* (*Hebertella*) *insculpta* Hall, *O.* (*Plectorthis*) *whitfieldi*, N. H. W., *Rhynchotrema capax* Conrad, Orthoceras sp. and a fragment of a species of Bumastus.

About two and one-half miles down the Little Turkey river from the village of Auburn, just below the wagon road near the middle of section 24 of Auburn township, a small stream has cut through the cherty layers of the Middle Maquoketa beds. From near the base of this zone the water falls about fifteen feet, down to the level of the river. In this gorge there is exposed a bed of blue colored shale immediately underlying the indurated layers of the Middle Maquoketa. This shale deposit is also the equivalent of number 6 in the Dover Mills section, and it has furnished the fossils, *Rafinesquina minnesotensis*, N. H. W., *Plectambonites sericea* Sowerby, *Strophomena incurvata* Shepard, *Orthis* (*Dinorthis*) *pectinella* (Emmons) Hall, *O.* (*Dalmanella*) *testudinaria* Dalman, *O.* (*Hebertella*) *insculpta* Hall, *O.* (*Plectorthis*) *whitfieldi*, N. H. W., *Rhynchotrema capax* Conrad, Orthoceras sp., *Trochoceras baeri* Meek, Bumastus sp. and a species of Pterygometopus.

The shale deposit of this same horizon is also well exposed, and attains a similar development, in the bed of Cascade gulch just below the hard, cherty layers of the Middle Maquoketa beds.

The Middle Maquoketa Division.—The entire thickness of the indurated, chert-bearing layers of the Middle Maquoketa deposit

is well exposed in the banks of Cascade gulch, about fifty rods above the point where this stream meets the river. The section here is as follows:

		FEET.
4.	Heavy layer of impure limestone, yellowish-gray in color and rather fine-grained in texture; containing a few chert nodules, but these are less abundant than in the preceding members; showing imperfect planes of bedding	5
3.	Bed of impure limestone in rather even layers two to six inches in thickness. The layers are largely composed of crowded masses of chert imbedded in the limestone matrix, or segregated along the lines of stratification; bearing *Streptelasma corniculum*, very large individuals of *Rafinesquina alternata* and of *Rhynchotrema capax* together with *Orthis* (*Dalmanella*) *testudinaria* and a second species of Orthis........................	13
2.	Bed made up of quite regular layers of fine-grained, impure limestone, six to eight or ten inches in thickness; containing very numerous concretions of chert, and having chert bands intercalated between the layers of limestone; the fossils *Rafinesquina alternata*, *Orthis* (*Dalmanella*) *testudinaria*, *O.* (*Hebertella*) *insculpta* and *Rhynchotrema capax* are present........................	20
1.	Thin layers of yellow colored, fine-grained, magnesian limestone, which breaks with a smooth fracture and appears homogeneous throughout; bearing few chert masses, and containing *Lingula iowensis*, and several individuals of one or more species of Orthoceras.....................	7

These resistant layers stand in vertical cliffs in the banks on either side of the stream, and they appear in the channel as an abrupt declivity over which the water flows in steep cascades.

A bluff, the materials of which belong to this same horizon, is exposed in the east bank of a small stream about one-half mile south of the village of Auburn, near the middle of section 35 of Auburn township. At this place the limestone is less magnesian than that described in the foregoing section. The ledge is made up of even layers which contain a large proportion of chert in the form of imbedded nodules and irregular bands. Along the banks of the Little Turkey river this phase is exposed at a number of points between Auburn and Eldorado. The en-

during character of the materials is manifest in the conspicuous bluff or terrace that flanks the valley a short distance back on either side of the flood plain. Occasionally a small stream has cut a narrow gorge through this ledge and has built a conspicuous alluvial fan of chert fragments where it debouches on the flood plain of the river. About three miles down the Little Turkey river from Auburn a cliff of these chert-bearing layers of the Middle Maquoketa phase borders the east side of the flood plain for a distance of twenty-five rods and to a height of about thirty-five feet.

FIG. 41. View in the abandoned clay pit of the Clermont Brick and Tile Company, showing the cherty, indurated layers of the Middle Maquoketa beds overlying the uppermost zone of the Lower Maquoketa shale. Clermont, Iowa.

Near the extreme northwest corner of section 6 of Dover township, the cherty limestone of this same horizon is well exposed in the banks of a small creek. The layers here are fairly pure carbonate of lime, with the exception of the great number of chert nodules which they carry. They are very hard, and break with a hackly fracture In a zone correspond-

ing with number 3, of the last section *Rafinesquina alternata* Conrad, was very abundant. The following fossils were also collected here: *Streptelasma corniculum* Hall, *Lingula iowensis* Owen, *Rafinesquina minnesotensis* N. H. W., *R. alternata* var. *loxorhytis* Meek, *Leptæna unicostata* N. & W., *Strophomena incurvata* Shepard, Strophomena sp., *Orthis (Dalmanites) testudinaria* Dalman, *O. (Hebertella) insculpta* Hall, *O. (Plectorthis) whitfieldi* N. H. W., *O. (Dinorthis) subquadrata* Hall, very large individuals of *Rhynchotrema capax* Conrad, *R. perlamellosa* Whitfield, and a species of Trochonema somewhat resembling *T. umbilicatum* Hall.

A bed of the Middle Maquoketa materials, which is the equivalent of numbers 1 and 2 of the foregoing section, is well shown overlying the upper portion of the Lower Maquoketa division in the abandoned clay pit of the Clermont Brick and Tile Company, a short distance north of Clermont. See figure 41. At this place the following section is exposed:

		FEET
5.	Bed of yellow colored dolomite, in layers one to three inches in thickness; nearly one-half of the material of these layers is composed of chert nodules and masses of about one inch in thickness	8
4.	Massive bed of yellow colored, magnesian limestone which shows indistinct lines of bedding, and contains a large amount of chert in the form of irregular nodules and more or less interrupted bands. The following fossils were found here: *Rafinesquina alternata*, Strophomena sp., *Orthis (Dalmanella) testudinaria*, *O. (Hebertella) insculpta*, *Rhynchotrema capax* and fragments of individuals of two species of Orthoceras....................	5
3.	Bed composed of two layers of yellow colored dolomite, which are respectively two and one-fourth and one and three-fourths feet in thickness. The exposed surfaces show numerous cavities from which small concretions have weathered. Small nodules of chert are quite numerous; the layers contain *Rafinesquina alternata*, *Orthis (Dalmanella) testudinaria* and *Rhynchotrema capax*..........	4
2.	Bed of arenaceo-magnesian limestone, rather homogeneous, yellowish in color, containing but few concretions of chert..........................	3
1.	Bed of yellowish-gray shale, quite hard, without evident planes of stratification, and carrying no fossils.......................................	14

In the section given above, number 1 is the equivalent of number 6 of the section at Dover Mills. It represents the upper portion of the Lower Maquoketa deposits. Numbers 2 and 3 together correspond with number 1 of the section of the cherty beds exposed in Cascade gulch, and represent the basal materials of the Middle Maquoketa. Numbers 4 and 5 combined are readily correlated with number 2 of the section in Cascade gulch. The even and indurated character of the layers of this division, and the very large amount of chert which they carry, make it an easy matter to distinguish the Middle Maquoketa beds from the shale deposits either above or below this chert-bearing phase. In our area the fossil *Rafinesquina alternata* var. *loxorhytis* Meek was found only at this horizon.

About one and one-half miles east of Brainard the Middle Maquoketa cherts appear to a height of twenty-five feet in the north bank of Otter creek.

At a point eighty rods southwest of the station at Brainard, near the middle of section 30 of Pleasant Valley township, a small quarry is worked in the south bank of Otter creek which shows the following succession of layers:

		FEET.
4.	Reddish colored clay, for the most part residual; barren of organic remains	2½
3.	Bed of yellow to gray colored, arenaceous shale, becoming blue in color towards the top, without fossils	3½
2.	Bed composed of narrow layers of arenaceo-magnesian limestone, yellowish-gray in color, and quite hard; containing a large admixture of shale, but no fossils	5
1.	Bed consisting of two layers of yellowish, impure limestone, each about two feet in thickness; containing small masses of calcite and an occasional nodule of chert	4

In the foregoing section, number 1 represents the uppermost deposits of the Middle Maquoketa beds, and corresponds with number 4 of the section of this horizon in Cascade gulch. Number 2 represents the transition materials from the Middle to the Upper Maquoketa deposits. These materials consist of five or six feet of alternating layers of arenaceo-magnesian

limestone, and lean, somewhat sandy, impure shale. The layers are four to eight inches in thickness and contain no fossils. At this place the transition to the shales of the Upper Maquoketa beds is much less abrupt than it appears in the channel of Cascade gulch. Numbers 3 and 4 of the section represent the basal portion of the Upper Maquoketa beds.

The Upper Maquoketa Division.—The Upper Maquoketa deposits can be well studied along the banks of Otter creek, and in the channels of the tributary streams, in the vicinity of the village of Brainard. Near the middle of the north side of section 24, Union township, the creek swings to the south and has exposed in its west bank a thickness of about fifty feet of blue, tenaceous shale. The bed here shows no trace of stratification, nor does it contain any fossils. Large, compound crystals of selenite are quite abundant in the clay. From the top of this bluff the inclination is rather gentle for about fifty feet more, up to the foot of the scarp of Niagara limestone. The base of the exposure is about twenty feet above the top of the Middle Maquoketa beds. The outcrop represents the middle and lower portion of the Upper Maquoketa.

At Patterson's spring, about one mile north of Brainard, the contact of the Maquoketa with the Niagara is well exposed. At this point, a short distance west of the middle of section 20 of Pleasant Valley township, the following section may be studied in a small ravine:

	FEET.
7. Bed composed of yellow colored, rather coarse-grained dolomite, in layers four to twelve inches in thickness; containing a few small nodules of chert, and occasional fossils..................	6
6. Bed of rather fine-grained, yellow colored, magnesian limestone, homogeneous in texture, evenly bedded, and breaks with clean fracture; containing no fossils or chert concretions..........	2
5. Bed composed of indurated layers of very fossiliferous, gray limestone, one to four inches in thickness, which are separated by narrow, softer seams of blue shale which also contain numerous fossils	2½

		FEET.
4.	Bed in which the calcareous layers are less indurated and thinner than in number 5 above, separated by narrow bands of blue shale. The material is very fossiliferous throughout, containing *Leptaena unicostata*, *Orthis occidentalis*, *Tentaculites sterlingensis* and other forms......	$1\frac{1}{2}$
3.	Layer of rather incoherent shale, blue or bluish-gray, or in places reddish-brown, in color; containing very numerous fossils, among which are a branching monticuliporoid, *Leptaena unicostata*, *Orthis occidentalis* and *O.* (*Platystrophia*) *biforata* var. *acutilirata*........................	2
2.	Layer of hard, bluish-gray shale; without fossils..	$\frac{5}{6}$
1.	Homogeneous, blue colored shale, very soft and plastic where soaked with water; containing small concretions of iron pyrites, and but few fossils..	14

The foregoing will be designated as the Patterson's Spring section. Upon following down the channel of this small stream, a vertical thickness of nearly one hundred feet of plastic, blue colored shale, quite similar to number 1 of the section, is passed over. Number 2 is a band of shale much more indurated than the great body of the shale seen at this place.

Numbers 3, 4 and 5 are exceedingly fossiliferous. Some of the calcareous layers are composed almost wholly of ramose colonies of a monticuliporoid, together with *Leptaena unicostata* Meek and Worthen, and a lesser number of detached valves of *Orthis occidentalis* Hall. *Leptaena unicostata* is exceedingly abundant at this horizon. The individuals are exceptionally large and well preserved, but it is very rarely that a ventral valve shows any trace of the median costa. Besides the above, the following fossils were collected from these uppermost members of the Maquoketa stage at Patterson's spring. Crania sp., *Streptelasma corniculum* Hall, *Rafinesquina minnesotensis* N. H. W., Leptaena sp., *Plectambonites sericea* Sowerby, *Strophomena trilobata* Owen, *Orthis* (*Platystrophia*) *biforata* var. *lynx* Eichwald, *O.* (*Platystrophia*) *biforata* var. *acutilirata* James, *Rhynchotrema capax* Conrad, *Zygospira modesta* Say., Bellerophon sp., *Cyclonema bilix* Conrad, *Tentaculites sterlingensis* Meek and Worthen, *Pterinea demissa* Conrad, *Ambonychia radiata* Hall, *A. intermedia* Meek and Worthen and *Calymene senaria* Conrad.

At the old Rawson's mill, a short distance north of the middle of the west side of section 3, Fairfield township, the following beds are exposed in the bluff that borders Bear creek on the east:

		FEET.
4.	Ledge of heavy layers of Niagara dolomite.......	16
3.	Bed of grayish-blue shale, near the top of which there are a few thin, indurated bands; fossiliferous throughout, containing *Streptelasma corniculum*, *Leptaena unicostata*, *Plectambonites sericea*, *Orthis occidentalis* and *Rhynchotrema capax*....................	14
2.	Weathered bed of gray shale, with somewhat indurated bands two to eight inches in thickness. The following fossils are abundant: *Plectambonites sericea*, *Orthis occidentalis*, *O.* (*Platystrophia*) *biforata* var., and *Rhynchotrema capax*...	18
1.	Bed of blue colored, plastic shale, carrying fine crystals of selenite, but containing no fossils...	35

In the above exposure the depth of the fossiliferous zone near the top of the Maquoketa is much greater than that of the corresponding phase at Patterson's spring, ten miles further north. It is possible that a portion of the materials that are exposed in number 2 of the Rawson's Mill section may have crept down the slope from a higher position, and that in reality they are a duplicate of number 3. There was no way of satisfactorily determining whether this is the case or not, but at no other place in the county, where the materials of this horizon are clearly exposed, does the fossiliferous zone attain a thickness of more than eight to twelve feet. About one mile west of Rawson's mill a shale bed corresponding with number 1 of the last section may be seen in the north bank of Bear creek. The materials here are blue in color and quite plastic. They contain numerous crystals of gypsum but no fossils.

Near the center of the north side of section 35 of Auburn township a small affluent joins the Little Turkey river from the east. A few rods north of the point where this stream discharges into the river the cherty, indurated layers at the top of the Middle Maquoketa beds are exposed to a height of eight feet above low water. Upon walking up the channel of the above mentioned stream the entire thickness of the Upper

Maquoketa beds is passed over. At this place the deposit has a depth of not less than one hundred feet. The material is bluish-gray in color, is quite plastic and, near the top, it contains the fossils *Streptelasma corniculum* Hall, *Leptaena unicostata* Meek and Worthen, *Plectambonites sericea* Sowerby, *Orthis occidentalis* Hall, *O. (Platystrophia) biforata* var. *acutilirata* James, *O. (Dalmanella) testudinaria* Dalman, and *Rhynchotrema capax*. Conrad. The transition to the overlying Niagara beds is well shown and the materials are not unlike those seen at Patterson's spring, although the number and variety of fossils is not so great as at the latter exposure.

Near the middle of the south side of section 21 of Illyria township, a short distance northwest of Wadena, the following succession of layers may be seen in the banks of a small ravine:

		FEET.
6.	Bed composed of layers of Niagara dolomite, six to eighteen inches in thickness, yellow in color; containing few fossils......	8
5.	Layer of yellowish-brown shale, strongly stained with iron.................................	1
4.	Gray colored shale in which are present iron-stained, indurated bands, three-fourths to one inch in thickness, which are crowded with poorly preserved fragments of shells. *Plectambonites sericea* and *Orthis occidentalis* were recognized.......	3½
3.	Indurated layers of limestone, two to seven inches in thickness, which are crowded with broken fragments of brachiopod shells, and separated one from another by bands of shale.	4
2.	Gray colored shale, containing small concretions of iron pyrites, and thin bands of iron-stained materials; no fossils	3
1.	Blue colored, plastic shale which breaks into irregular fragments, and contains no fossils...	21

In the above section numbers 1 and 2 are the equivalents of numbers 1 and 2 of the section at Patterson's spring. Numbers 3 to 5 inclusive of the foregoing section correspond with the horizon represented by numbers 3 to 5 inclusive of the Patterson's Spring exposure. Number 6 above represents the basal portion of the Niagara limestone at this place, and it is the correlative of numbers 6 and 7 inclusive of the Patterson's Spring section.

Another exposure very similar to the last appears in the bed of a ravine near the southeast corner of section 1, Fairfield township. At this place the ledge of Niagara dolomite is eight feet in thickness, and is composed of quite regular, nonfossiliferous layers, six to eighteen inches in thickness. Below this dolomite there appears about ten feet of the uppermost layers of the Maquoketa, consisting of narrow, indurated, calcareous bands, separated one from another by seams of shale. Both the shale and the limestone layers carry numerous individuals of *Plectambonites sericea*, *Orthis occidentalis* and other fossils characteristic of this horizon. Below the transition beds there may be seen about thirty feet of blue colored nonfossiliferous shale, containing small concretions of iron pyrites.

The materials of the Upper Maquoketa beds are also well exposed in the town of Saint Lucas, near the northern limits of the county. They outcrop along the wagon road in the hill upon the summit of which the large Catholic church is built. The materials at this place do not differ in any special way from those of the Upper Maquoketa beds at Auburn and at Patterson's spring. In the upper part there were found the fossils that are characteristic of this zone at other places in the county.

The deposits of the Upper Maquoketa beds, and the contact of these with the overlying Niagara limestone, appear in the channel of a number of the smaller tributaries of the Volga river, Otter creek, the Little Turkey and the Turkey rivers. As a general thing the contact of the Niagara with the Maquoketa shale is well exposed in the beds of these streams, if no great thickness of the Niagara is present at the point where the water cuts through the limestone and into the underlying shale. When the depth of the Niagara materials is great, such contact is usually concealed by the large limestone masses that have fallen down from above, and which the waters are unable to transport further down the channels.

From the foregoing descriptions it will have been noticed that the lithological characters of the Upper Maquoketa beds in Fayette county are quite unlike those of the Middle and the Lower Maquoketa deposits. They are very similar, however, to those of the Upper Maquoketa materials in the county of

Dubuque. In our area the assemblage of fossils that occurs in the zone near the top of the Upper Maquoketa is also quite different from the fauna of the Middle or the Lower Maquoketa beds, but it is practically identical with that of the corresponding horizon further south, in Dubuque county. Professor Calvin* has called attention to the fact that the fauna that is found in the materials near the top of the Upper Maquoketa, in Dubuque county, is practically the same as that which is encountered in the Cincinnati shales of southwestern Ohio. The fossils of the Upper Maquoketa beds in Fayette county make still more complete the correspondence of the biologic contents of the Upper Maquoketa of Iowa with those of the Cincinnati shales in Ohio and Indiana.

From a comparison of the foregoing sections a general section of the Maquoketa strata of Fayette county may be constructed as follows:

GENERAL SECTION OF THE MAQUOKETA SHALES.

		FEET.
13.	Bed composed of bands of soft, bluish-gray shale, two to four inches in thickness, which alternate with thin layers of limestone one to three inches in thickness, having a band of reddish shale two feet in thickness at the base. The materials are fossiliferous throughout, containing numerous colonies of a branching Monticuliporoid, *Leptaena unicostata*, *Plectambonites sericea*, *Strophomena trilobata*, *Orthis occidentalis*, *O.* (*Platystrophia*) *biforata* var., *Rhynchotrema capax*, *Cyclonema bilix* and *Ambonychia radiata*........................	8-12
12.	Bed of blue colored, plastic shale, without distinct planes of bedding; containing small concretions of iron pyrites in the upper part and numerous large crystals of selenite below; bearing no fossils................	95-110
11.	Transition beds from the Middle to the Upper Maquoketa; consisting of layers of yellowish arenaceo-magnesian limestone, three to eight inches in thickness alternating with bands of dry, indurated, impure shale; without fossils	3-5

*Calvin: Geology of Dubuque County, Iowa, Geol. Surv., Vol. X, p. 444.

		FEET.
10.	Massive bed of yellow colored limestone, which in some places is dolomitic, sometimes showing indistinct planes of bedding that separate the ledge into imperfect layers, six to twelve inches in thickness; bearing few fossils, and occasional concretions of chert..............	5
9.	Bed of impure limestone (in places dolomitic) made up of quite regular layers, two to six inches in thickness; containing a large quantity of chert in the form of nodules and imperfect bands; bearing the fossils *Streptelasma corniculum*, *Rafinesquina alternata*, *R. alternata*, var. *loxorhytis*, *Leptaena unicostata* and *Rhynchotrema capax*	12-14
8.	Bed of fine-grained, impure limestone, in even layers six to ten inches in thickness, consisting largely of chert nodules imbedded in the layers or of chert bands segregated along the planes of bedding; containing large individuals of *Rafinesquina alternata*, *Strophomena incurvata*, *Orthis* (*Dalmanella*) *testudinaria*, *O.* (*Hebertella*) *insculpta*, and *Rhynchotrema capax*....	18-21
7.	Massive bed of yellow colored, fine-grained dolomite, which in some places is divided into thin layers; containing a number of chert nodules, and bearing *Lingula iowensis* and Orthoceras sp.	5 7
6.	Bed of bluish colored, plastic, rather fine-grained shale; in places containing numerous fossils among them *Rafinesquina alternata*, *R. minnesotensis*, *Plectambonites sericea*, *Strophomena incurvata*, *Orthis* (*Dalmanella*) *testudinaria*, *Rhynchotrema capax*, and *Trochoceras baeri?*..	10-14
5.	Bed of lean, yellowish-gray shale, in places somewhat arenaceous; containing, in the lower part, thin bands of impure limestone, three to six inches in thickness; bearing *Strophomena planumbona*, *Orthis* (*Dinorthis*) *subquadrata*, *O.* (*Hebertella*) *insculpta* and *O.* (*Plectorthis*) *whitfieldi*....................................	10-13
4.	Bed composed of layers of yellowish-gray shale, three to six inches in thickness, separated by bands of impure limestone about equal in thickness to the seams of shale, becoming more calcareous below; bearing numerous nodules of chert, and containing *Plectambonites sericea*, *Orthis* (*Hebertella*) *insculpta*, *Rhynchotrema inaequivalvis*, *Murchisonia gracilis*, *Pterygometopus callicephalus* and *Ceraurus pleurexanthemus*......................	14-16

	FEET.
3. *Nileus vigilans* zone: consisting of a bed of gray colored limestone in layers one to four inches in thickness, which are separated from one another by thin bands of gray shale; containing *Nileus vigilans*, *Calymene senaria*, *Pterygometopus callicephalus* and *Ceraurus icarus*	13–16
2. Bed of bluish or yellowish colored shale, usually dry and indurated, in layers two or three inches in thickness, between which thin bands of limestone or irregular seams of chert nodules are intercalated; among the fossils are *Lophospira quadrisulcata* and *Orthoceras bilineatum*	15–18
1. *Isotelus maximus* zone: composed of layers of bluish, fine-grained, argillaceous limestone, four to eight inches in thickness, alternating with bands of bluish-gray shale of about the same thickness as the calcareous layers. The indurated materials break with a smooth fracture and contain very abundant fragments of the trilobite *Isotelus maximus*	14–16

A study of the above section will show that the strata of the Maquoketa stage in Fayette county attain a maximum thickness of about two hundred and sixty feet. Numbers 1 to 6 inclusive constitute the Lower Maquoketa beds which have a thickness of more than ninety feet. Numbers 7 to 11 inclusive belong to the Middle Maquoketa division, with a thickness of about fifty feet. Numbers 12 and 13 represent the deposits of the Upper Maquoketa which have a maximum thickness of about one hundred and twenty feet.

The fossils of the Maquoketa are of more than usual interest both on account of the number and variety of the forms and from the fact that the fauna of the Upper Maquoketa beds presents such a marked contrast with that of the Middle and Lower Maquoketa divisions. Below is given a list of the more common species that occur in Fayette county. These will furnish a general idea of the forms of life that flourished in this portion of that old Ordovician sea.

FOSSILS OF THE MAQUOKETA SHALES.

Astylospongia? sp.†
Hindia parva Ulrich.†
Streptelasma corniculum Hall.* ‡ †
Streptelasma sp.†
Lingula iowensis Owen.‡ †
Crania sp.*
Rafinesquina alternata Conrad.* ‡ †
R. alternata var. *loxorhytis* Meek.‡
R. minnesotensis N. H. Winchell.* ‡ †
Leptæna unicostata Meek and Worthen.* †
Plectambonites sericea Sowerby.* ‡ †
Strophomena planumbona Hall.†
S. fluctuosa Billings.†
S. incurvata Shepard.‡ †
S. trilobata Owen.*
Strophomena sp. †
Clitambonites diversa ? Shaler.†
Parastrophia sp.†
Orthis (*Dinorthis*) *subquadrata* Hall.†
O. (*Dinorthis*) *pectinella* (Emmons) Hall.†
O. occidentalis Hall.*
O. (*Hebertella*) *insculpta* Hall.‡ †
O. (*Plectorthis*) *whitfieldi* N. H. Winchell.†
O. (*Plectorthis*) *plicatella* Hall.†
O. (*Plectorthis*) *fissicosta* Hall.†
O (*Dalmanella*) *testudinaria* Dalman.* ‡ †
O (*Dalmanella*) *hamburgensis* Walcott.†
O. (*Platystrophia*) *biforata* var. *lynx* Eichwald.* †
O. (*Platystrophia*) *biforata* var. *acutilirata* James *
Rhynchotrema capax Conrad.* ‡ †
R. perlamellosa Whitfield.†
R. inæquivalvis Castlenau.†
Rhynchonella neenah Whitfield.†
Zygospira modesta (Say) Hall.* †
Z. recurvirostra Hall.†
Murchisonia gracilis Hall.†
Lophospira cf. *conoidea* U.*
L. quadrisulcata U. & S.†
Bellerophon bilobatus Sowerby †
Bellerophon sp.†
Helicotoma sp.*
Trochonema umbilicatum Hall.†
Trochonema sp.†
Gyronema pulchellum ? W. and S.†
Cyclonema bilix Conrad.*

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*Collected from the Upper Maquoketa beds.
‡ Found in the Middle Maquoketa.
† Occur in the Lower Maquoketa.

Holopea cf. *concinnula* U. & S.†
Tentaculites sterlingensis Meek and Worthen.*
Conularia sp.†
Pterinea demissa Conrad.*
Ambonychia radiata Hall.*
A. intermedia Meek and Worthen.*
Ambonychia sp.*
Orthoceras sociale Hall.†
O. bilineatum Hall.†
Orthoceras sp.†
Cameroceras proteiforme Hall.†
Cyrtoceras camurum? Hall.†
Trochoceras? baeri M. & W.*
Gyroceras sp.†
Isotelus maximus Locke.†
Isotelus sp.†
Bumastus orbicaudatus Billings.†
Nileus vigilans Meek and Worthen.†
Calymene senaria Conrad.* †
Ceraurus icarus Billings.†
C. pleurexanthemus Green.†
Pterygometopus callicephalus Hall.†
Dalmanites sp.†

The presence of an impervious body of shale beneath the porous, and more or less jointed beds of Niagara limestone determines a zone of springs along the line of contact of the Niagara with the Maquoketa shale. Occasionally as at the Falling Spring, shown in figure 42, the water issues a few feet above the base of the Niagara. In such places it would seem probable that a large mass of the limestone had slipped downward from its original position, owing to the more rapid weathering of the shales upon which it rested. In that event the water, which further back in the bank follows near the line of contact, would find a ready outlet along the planes of bedding when it encountered the ledge of Niagara limestone.

* Collected from the Upper Maquoketa beds.
‡ Found in the Middle Maquoketa.
† Occur in the Lower Maquoketa.

Niagara Series.

DELAWARE STAGE.

The rocks of the Delaware stage immediately underlie the superficial materials over an exceedingly irregular area in the northern, eastern and southern portions of Fayette county. By referring to the Geological map it will be seen that they are

FIG. 42. Falling Spring near the middle of the south side of section 35, Auburn township. The water issues a few feet above the top of the Maquoketa shales.

present over the greater portion of Auburn township, except where they have been eroded in the development of the gorges occupied by the Turkey and Little Turkey rivers. The most westerly appearance of the Niagara limestone, in the northern

portion of the county, is in the bed and banks of Crane creek near the middle of section 34, Eden township, where it outcrops to a height of a few feet. Following down the creek from this point the Niagara disappears for a distance of a mile and one-half, after which it is again seen in the banks more or less continuously down to the junction of this stream with the Little Turkey river.

The Delaware deposits appear in the extreme northeast corner of Windsor township, and in section 25 of Eden. They are present over the area south of the Turkey river, in the townships of Dover, Clermont and Pleasant Valley. They cap a few disconnected knobs in sections 24, 25 and 26 of Clermont township, and sections 1 and 12 of Pleasant Valley. They are the uppermost indurated rocks in the northern and eastern portions of Union township, the eastern portion of Westfield and Smithfield, and the whole of the townships of Illyria and Fairfield. The unconsolidated, mantle materials that appear at the surface over all of the southern tier of townships, with the exception of the extreme southwest corner of Oran, probably rest upon these enduring layers of the Delaware stage. The strata of the Niagara do not attain anything like the thickness in Fayette county that they do further to the southeast in the county of Delaware, where they reach a thickness of more than two hundred feet. It seems certain that the aggregate thickness of the Niagara limestone constantly decreases towards the northwest, from the southern border of Fayette county. At the "Devil's Backbone," about two miles southeast of West Union, the complete section of the Niagara may be seen within a distance of fifty rods. At this place the entire thickness of the beds does not exceed seventy feet.

In the wagon road a short distance east of the middle of section 33 of Auburn township, the Devonian limestone appears in the top of the hill as one approaches the Little Turkey river from the south. At a distance of eight rods from this place the Maquoketa shale is exposed in a small ravine to a height of twenty feet above the level of the river, and it is succeeded by a cliff of Niagara limestone. The thickness of the Niagara beds at this place does not exceed forty feet.

A few rods east of the wagon bridge, near the middle of the south side of section 30, Auburn township, about six feet of the Maquoketa shale outcrop in the north bank of the river. The flood plain here is bounded by low bluffs of Niagara limestone to a height of thirty feet above the bed of the stream. One mile to the southwest from this place the top of a ledge of Niagara appears in the north bank of Crane creek fifteen feet above the water and it is overlain by about twenty feet of Devonian limestone. It would seem probable that in this vicinity the Niagara strata are not more than twenty-five feet in thickness. Still further towards the northwest, in Winneshiek and Howard counties, the Niagara limestone has in places entirely faded out, and the Maquoketa shales are immediately succeeded by strata of Devonian age.*

Over the southern portion of the county the Niagara limestone is a rather coarse-grained, yellowish-brown dolomite. In some places it contains an admixture of sand, and it usually carries a large number of chert nodules. In the vicinity of West Union the material is often a fine-grained, very hard limestone, light gray in color, and contains a very large amount of chert concretions. Near the small town of Auburn the Niagara is prevailingly a gray limestone which reacts vigorously with cold hydrochloric acid. The layers are two to six feet in thickness. They are somewhat vesicular, and show no traces of lamination planes. They are very hard and, when broken, they cleave as readily in one direction as another into fragments of irregular shape.

The absence of dolomitization and the remarkable purity of the Niagara limestone in this vicinity will appear from an analysis of representative samples taken from the blocks of Niagara that overlook the village of Auburn from the east. The analysis was made by the Survey Chemist, Prof. L. G. Michael, and shows the following:

Calcium carbonate, $Ca\,CO_3$	98.52
Silica, SiO_2	.68
Alumina and iron, $Al_2\,O_3$, $Fe_2\,O_3$	.50

*Calvin: Iowa Geol. Surv., Vol. XIII, pp. 47 and 48.

Here, as everywhere, the enduring ledges are cliff-forming to a remarkable degree. Where a region has suffered extensive erosion they impress themselves upon the topography to an extent out of all proportion to the thickness of the beds.

Exposures.—In the northeast ¼ of section 24, Clermont township, Mr. Wilkes Williams operates a quarry in the lower layers of the Niagara limestone. The section at this place is as follows:

	FEET.
8. Bed of reddish colored clay, largely residual, but containing occasional pebbles and small bowlders of greenstone and granite	3
7. Bed of much decayed, yellow colored dolomite, containing very abundant nodules of chert; long exposed surfaces present numerous cavities from which chert masses have weathered; lamination planes irregular, and imperfectly developed, indicated by bands of chert	14
6. Layer of coarse-grained, yellow colored dolomite, which contains a large amount of chert in the upper part	2
5. Heavy ledge of dolomite, yellow in color and rather coarsely granular in texture, without chert	3½
4. Layer of coarse-grained dolomite, yellow in color, containing no chert	1
3. Regular layer of rather fine-grained dolomite, without chert	1⅝
2. Layer of yellow colored dolomite, resembling number 1 in texture; two and one-half feet in thickness at the south end of the quarry, increasing to four feet in thickness at the north end	4
1. Heavy ledge of homogeneous, fine-grained dolomite, with no tendency to split along planes of lamination, and containing no fossils or chert nodules; increasing in thickness toward the north	4

The first member of the foregoing section rests upon the top of the Maquoketa shale, and represents the basal layer of the Niagara limestone. This layer together with numbers 2 and 3 have an even texture, and carry no fossils or chert masses. They furnish excellent materials for sills, water tables and general range work. The stone is quarried in large blocks, and

then sawed into any dimensions desired. These members supply all of the material for dressed stone and sawed work that the quarry produces. Numbers 4 and 5 are also free from chert, and furnish stone suitable for bridge copings and general masonry. No use is made of the upper layers in which chert masses are numerous and cavities abundant.

Number 8 consists of a tough red clay in which are mingled chert fragments and occasional pebbles and small

FIG. 42. View of the Niagara limestone in the old Williams and Davis quarry, southeast ¼ of section 15, Union township. The stone here represents the upper portion of the Niagara in Fayette county.

bowlders. The clay is largely a product of rock decay in situ, to which the name "geest" has been applied. Such residual products are frequently exposed along the hillslopes over the Niagara area.

If the lower, fine-grained, quarry-stone layers persist to the southward, they thin out quite rapidly. In the Patterson's Spring section number 6, which consists of layers of fine-grained, homogeneous materials having an aggregate thickness of two feet, seems to be all that corresponds with the lower fourteen feet of quarry stone in Williams' quarry.

A large amount of chert is usually present throughout the middle portion of the Niagara beds in Fayette county. This characteristic is conspicuous at the old Williams and Davis quarry, which has been opened in the north bank of Otter creek, near the northeast corner of section 22 of Union township. The characters of the strata appear in figure 43. The following succession of layers is exposed here:

		FEET.
8.	Layer of impure limestone, yellowish gray in color, and fine-grained; no chert	1½
7.	Ledge of gray colored, very hard limestone, in places showing a tendency to separate into layers eight, three, two, four and eight inches in thickness respectively; without fossils, and containing no chert	2
6.	Much shattered layer of gray limestone, containing a very large amount of chert in the form of nodules and irregular masses	1½
5.	Layer of dense, fine-grained limestone, gray in color, without fossils, almost free from chert in the middle portion....	1
4.	Bed of gray limestone consisting of layers two to four inches in thickness, which are separated from one another by bands of chert	4
3.	Bed of fine-grained, gray limestone, in two layers one and one-third feet and one foot in thickness; containing much chert and separated by a chert seam..........................	2½
2.	Massive layer of gray limestone, containing a very large amount of chert in the form of bands and imbedded nodules...........................	3½
1.	Bed of gray, cherty limestone, in layers three to six inches in thickness.................	4

In the above section the horizon of number 1 is very near that of the top of number 7 in the Williams' Quarry section. The very great amount of chert which the layers contain renders them unfit for use except as riprap, ballast or macadam.

The materials in this quarry are not dolomitized with the exception of a zone a few feet in thickness near the top. The rock is very fine-grained and sub-crystalline in texture. In the first member there is a zone in which indistinct traces of a coral having very small tubes, or of a Stromatoporoid, are very abundant, but in the process of alteration which the rocks have undergone the structure of the fossils has been largely obliterated.

FIG. 44. Section of the Niagara limestone at the "Devil's Backbone", two and one-half miles southeast of West Union. Nearly the entire thickness of the Niagara in the county is here exposed.

An abandoned quarry in the northeast ¼ of section 21 of Fairfield township shows a ledge of chert-bearing, nonfossiliferous layers which belong to the upper portion of the Niagara

Niagara Series.

DELAWARE STAGE.

The rocks of the Delaware stage immediately underlie the superficial materials over an exceedingly irregular area in the northern, eastern and southern portions of Fayette county. By referring to the Geological map it will be seen that they are

FIG. 42. Falling Spring near the middle of the south side of section 35, Auburn township. The water issues a few feet above the top of the Maquoketa shales.

present over the greater portion of Auburn township, except where they have been eroded in the development of the gorges occupied by the Turkey and Little Turkey rivers. The most westerly appearance of the Niagara limestone, in the northern

portion of the county, is in the bed and banks of Crane creek near the middle of section 34, Eden township, where it outcrops to a height of a few feet. Following down the creek from this point the Niagara disappears for a distance of a mile and one-half, after which it is again seen in the banks more or less continuously down to the junction of this stream with the Little Turkey river.

The Delaware deposits appear in the extreme northeast corner of Windsor township, and in section 25 of Eden. They are present over the area south of the Turkey river, in the townships of Dover, Clermont and Pleasant Valley. They cap a few disconnected knobs in sections 24, 25 and 26 of Clermont township, and sections 1 and 12 of Pleasant Valley. They are the uppermost indurated rocks in the northern and eastern portions of Union township, the eastern portion of Westfield and Smithfield, and the whole of the townships of Illyria and Fairfield. The unconsolidated, mantle materials that appear at the surface over all of the southern tier of townships, with the exception of the extreme southwest corner of Oran, probably rest upon these enduring layers of the Delaware stage. The strata of the Niagara do not attain anything like the thickness in Fayette county that they do further to the southeast in the county of Delaware, where they reach a thickness of more than two hundred feet. It seems certain that the aggregate thickness of the Niagara limestone constantly decreases towards the northwest, from the southern border of Fayette county. At the "Devil's Backbone," about two miles southeast of West Union, the complete section of the Niagara may be seen within a distance of fifty rods. At this place the entire thickness of the beds does not exceed seventy feet.

In the wagon road a short distance east of the middle of section 33 of Auburn township, the Devonian limestone appears in the top of the hill as one approaches the Little Turkey river from the south. At a distance of eight rods from this place the Maquoketa shale is exposed in a small ravine to a height of twenty feet above the level of the river, and it is succeeded by a cliff of Niagara limestone. The thickness of the Niagara beds at this place does not exceed forty feet.

A few rods east of the wagon bridge, near the middle of the south side of section 30, Auburn township, about six feet of the Maquoketa shale outcrop in the north bank of the river. The flood plain here is bounded by low bluffs of Niagara limestone to a height of thirty feet above the bed of the stream. One mile to the southwest from this place the top of a ledge of Niagara appears in the north bank of Crane creek fifteen feet above the water and it is overlain by about twenty feet of Devonian limestone. It would seem probable that in this vicinity the Niagara strata are not more than twenty-five feet in thickness. Still further towards the northwest, in Winneshiek and Howard counties, the Niagara limestone has in places entirely faded out, and the Maquoketa shales are immediately succeeded by strata of Devonian age.*

Over the southern portion of the county the Niagara limestone is a rather coarse-grained, yellowish-brown dolomite. In some places it contains an admixture of sand, and it usually carries a large number of chert nodules. In the vicinity of West Union the material is often a fine-grained, very hard limestone, light gray in color, and contains a very large amount of chert concretions. Near the small town of Auburn the Niagara is prevailingly a gray limestone which reacts vigorously with cold hydrochloric acid. The layers are two to six feet in thickness. They are somewhat vesicular, and show no traces of lamination planes. They are very hard and, when broken, they cleave as readily in one direction as another into fragments of irregular shape.

The absence of dolomitization and the remarkable purity of the Niagara limestone in this vicinity will appear from an analysis of representative samples taken from the blocks of Niagara that overlook the village of Auburn from the east. The analysis was made by the Survey Chemist, Prof. L. G. Michael, and shows the following:

Calcium carbonate, $Ca\,CO_3$	98.52
Silica, SiO_2	.68
Alumina and iron, $Al_2\,O_3$, $Fe_2\,O_3$	.50

*Calvin: Iowa Geol. Surv., Vol. XIII, pp. 47 and 48.

Syringopora tenella. In the residual chert masses scattered over the slope, above the ledge, there also occur numerous very large casts of *Pentamerus oblongus*.

The Niagara strata of our area probably attain their greatest thickness in the southeastern portion of the county. The presence in abundance, of casts of large individuals of *Pentamerus oblongus* in the residual chert masses that are scattered over the slopes, in Smithfield township, and the absence of such remains in the Niagara deposits of the central and northern portions of the county, would indicate that the Niagara strata of Fayette county belong to a horizon below the true *Pentamerus oblongus* zone. It seems probable that the materials of the *Pentamerus oblongus* horizon were once the uppermost deposits over only the southeastern portion of the area, and that they have subsequently been removed by the agents of denudation. If this inference is correct, the uppermost deposits of the Delaware stage in Fayette county belong to a horizon more than one hundred feet below the latest of the Niagara deposits that appear in the county of Delaware. There are indications, too, that the lower layers of the Niagara in our area correspond with layers which, in Delaware county, occupy a position several feet above the base of the Delaware stage. In short, it is probable that both the uppermost strata and the lowermost members of the Niagara beds, which are encountered in Delaware county, fade out towards the northwest, in the county of Fayette.

Devonian System.

WAPSIPINICON STAGE.

Deposits representing the Middle Devonian series immediately underlie the superficial materials over the central and western portions of our area, covering nearly one-half of the surface of Fayette county. These rocks belong to the two lowermost stages of the series, the Wapsipinicon and the Cedar

then sawed into any dimensions desired. These members supply all of the material for dressed stone and sawed work that the quarry produces. Numbers 4 and 5 are also free from chert, and furnish stone suitable for bridge copings and general masonry. No use is made of the upper layers in which chert masses are numerous and cavities abundant.

Number 8 consists of a tough red clay in which are mingled chert fragments and occasional pebbles and small

FIG. 43. View of the Niagara limestone in the old Williams and Davis quarry, southeast ¼ of section 15, Union township. The stone here represents the upper portion of the Niagara in Fayette county.

bowlders. The clay is largely a product of rock decay in situ, to which the name "geest" has been applied. Such residual products are frequently exposed along the hillslopes over the Niagara area.

Here, as everywhere, the enduring ledges are cliff-forming to a remarkable degree. Where a region has suffered extensive erosion they impress themselves upon the topography to an extent out of all proportion to the thickness of the beds.

Exposures.—In the northeast ¼ of section 24, Clermont township, Mr. Wilkes Williams operates a quarry in the lower layers of the Niagara limestone. The section at this place is as follows:

		FEET.
8.	Bed of reddish colored clay, largely residual, but containing occasional pebbles and small bowlders of greenstone and granite............	3
7.	Bed of much decayed, yellow colored dolomite, containing very abundant nodules of chert; long exposed surfaces present numerous cavities from which chert masses have weathered; lamination planes irregular, and imperfectly developed, indicated by bands of chert...........	14
6.	Layer of coarse-grained, yellow colored dolomite, which contains a large amount of chert in the upper part..................................	2
5.	Heavy ledge of dolomite, yellow in color and rather coarsely granular in texture, without chert..	3½
4.	Layer of coarse-grained dolomite, yellow in color, containing no chert..........................	1
3.	Regular layer of rather fine-grained dolomite, without chert..................................	1⅝
2.	Layer of yellow colored dolomite, resembling number 1 in texture; two and one-half feet in thickness at the south end of the quarry, increasing to four feet in thickness at the north end..	4
1.	Heavy ledge of homogeneous, fine-grained dolomite, with no tendency to split along planes of lamination, and containing no fossils or chert nodules; increasing in thickness toward the north..	4

The first member of the foregoing section rests upon the top of the Maquoketa shale, and represents the basal layer of the Niagara limestone. This layer together with numbers 2 and 3 have an even texture, and carry no fossils or chert masses. They furnish excellent materials for sills, water tables and general range work. The stone is quarried in large blocks, and

then sawed into any dimensions desired. These members supply all of the material for dressed stone and sawed work that the quarry produces. Numbers 4 and 5 are also free from chert, and furnish stone suitable for bridge copings and general masonry. No use is made of the upper layers in which chert masses are numerous and cavities abundant.

Number 8 consists of a tough red clay in which are mingled chert fragments and occasional pebbles and small

FIG. 48. View of the Niagara limestone in the old Williams and Davis quarry, southeast ¼ of section 15, Union township. The stone here represents the upper portion of the Niagara in Fayette county.

bowlders. The clay is largely a product of rock decay in situ, to which the name "geest" has been applied. Such residual products are frequently exposed along the hillslopes over the Niagara area.

If the lower, fine-grained, quarry-stone layers persist to the southward, they thin out quite rapidly. In the Patterson's Spring section number 6, which consists of layers of fine-grained, homogeneous materials having an aggregate thickness of two feet, seems to be all that corresponds with the lower fourteen feet of quarry stone in Williams' quarry.

A large amount of chert is usually present throughout the middle portion of the Niagara beds in Fayette county. This characteristic is conspicuous at the old Williams and Davis quarry, which has been opened in the north bank of Otter creek, near the northeast corner of section 22 of Union township. The characters of the strata appear in figure 43. The following succession of layers is exposed here:

		FEET.
8.	Layer of impure limestone, yellowish gray in color, and fine-grained; no chert	1½
7.	Ledge of gray colored, very hard limestone, in places showing a tendency to separate into layers eight, three, two, four and eight inches in thickness respectively; without fossils, and containing no chert	2
6.	Much shattered layer of gray limestone, containing a very large amount of chert in the form of nodules and irregular masses	1½
5.	Layer of dense, fine-grained limestone, gray in color, without fossils, almost free from chert in the middle portion	1
4.	Bed of gray limestone consisting of layers two to four inches in thickness, which are separated from one another by bands of chert	4
3.	Bed of fine-grained, gray limestone, in two layers one and one-third feet and one foot in thickness; containing much chert and separated by a chert seam	2½
2.	Massive layer of gray limestone, containing a very large amount of chert in the form of bands and imbedded nodules	3½
1.	Bed of gray, cherty limestone, in layers three to six inches in thickness	4

In the above section the horizon of number 1 is very near that of the top of number 7 in the Williams' Quarry section. The very great amount of chert which the layers contain renders them unfit for use except as riprap, ballast or macadam.

The materials in this quarry are not dolomitized with the exception of a zone a few feet in thickness near the top. The rock is very fine-grained and sub-crystalline in texture. In the first member there is a zone in which indistinct traces of a coral having very small tubes, or of a Stromatoporoid, are very abundant, but in the process of alteration which the rocks have undergone the structure of the fossils has been largely obliterated.

FIG. 44. Section of the Niagara limestone at the "Devil's Backbone", two and one-half miles southeast of West Union. Nearly the entire thickness of the Niagara in the county is here exposed.

An abandoned quarry in the northeast ¼ of section 21 of Fairfield township shows a ledge of chert-bearing, nonfossiliferous layers which belong to the upper portion of the Niagara

deposits, and which are probably the equivalent of the layers seen in the Williams and Davis quarry. Materials similar to the above are also encountered along a stream a short distance north of Arlington.

A few rods west of the Williams and Davis quarry, a cliff of Niagara limestone, sixty feet in height, is exposed in the north bank of the creek, see figure 44. That the basal layer in this bluff is but a very few feet above the Maquoketa shale, if indeed it does not rest upon the Maquoketa, is shown by the fact that fifteen rods down the creek from this point the shale appears in the bank to a height of eight feet above the water. That the uppermost layer of the bluff is only a very few feet below the base of the Devonian, if its horizon is not immediately below the Devonian, appears from the fact that in the railroad cut, about thirty rods southwest of this point, the top of the Niagara is well exposed at no greater altitude than the top of the bluff. In the cut, the Niagara is succeeded by a bed of fine-grained, finely laminated Devonian limestone, four and one-half feet in thickness. It seems certain that the aggregate thickness of the Niagara strata in this region is not more than seventy feet.

Few fossils were found in any of the above mentioned exposures of the Niagara, and none of these were sufficiently well preserved for identification. Where the layers outcrop in a nearly east and west direction, in the bluff, they appear horizontal, as is shown in figure 44. Where these layers are seen in a north and south direction, in the railroad cut, their position is also nearly horizontal, but they present gentle undulations six inches to one foot in vertical height. That portion of the Niagara immediately underlying the Devonian in this cut could not be satisfactorily studied, on account of the steepness of the face of the ledge.

The uppermost layers of Niagara limestone, and the succeeding Devonian strata, can be observed under more favorable conditions about three and one-half miles south, and one and one-half miles west of this cut. There is a continuous outcrop for several rods, in the south bank of a small creek, a short distance east of the center of section 5, Westfield township. The layers are as follows:

		FEET.
7.	Bed composed of fragments of drab colored, fine-grained limestone, imbedded in a matrix of calcareous material which is also fine-grained in texture but lighter in color, without fossils; the layers show slight undulations. Lower Davenport breccia........................	12
6.	Bed composed of fine-grained, yellowish colored limestone which is very finely laminated; upon weathering the material splits along the lamination planes into thin, fissile fragments; without fossils. A few feet at the top somewhat talus-covered..................................	9
5.	Irregular band of yellow colored dolomite, coarse-grained in texture, in places appearing somewhat arenaceous; nonfossiliferous.............	1½
4.	Bed of yellow, impure dolomite, in layers four to eight inches thick; bearing some chert, and containing *Favosites favosus* and *Halysites catenulatus*................................	3
3.	Bed of vesicular dolomite, coarsely granular in texture, and yellow in color, made up of layers two to six inches in thickness, which contain *Favosites favosus* and *Halysites catenulatus* besides a number of brachiopods; nodules of chert are not rare............................	5
2.	Layer of porous, yellowish-brown dolomite, containing many concretions of chert, and bearing the fossils *Favosites favosus*, *Halysites catenulatus* and a species of Orthoceras..............	1 1/6
1.	Layer of yellowish-brown dolomite, somewhat sandy in places, containing chert concretions; to level of the water..........................	1½

In the above, which will be referred to as the Niagara-Devonian Contact section, numbers 6 and 7 represent Devonian limestone. The line of separation of the Niagara from the Devonian would be drawn between numbers 5 and 6. The change in the lithology of the materials above and below this line is very marked. The Niagara layers embrace numbers 1 to 5 inclusive. The material is coarsely granular, and in some parts of the exposure it is distinctly arenaceous. The rock is a yellowish-brown dolomite and contains such characteristic Niagara fossils as *Streptelasma spongaxis* Rominger, *Favosites favosus* Goldfuss, *F. niagarensis* Hall, *Halysites catenulatus* Linn., *Orthothetes subplana* Conrad, *Orthis flabellites* Hall, *Uncinulus stricklandi* Sowerby, *Homœospira apriniformis* Hall, and *Camarotœchia neglecta* Hall.

Niagara layers belonging to the same horizon as numbers 1 to 5 of the foregoing section, are well exposed at the Westfield bridge, in the northwest ¼ of section 29, Westfield township. At this place there is a thickness of twenty-two feet of yellow, vesicular dolomite which carries numerous chert nodules, and contains *Favosites favosus* Goldfuss, *Halysites catenulatus* Linn. and other characteristic fossils of the Delaware stage. The Niagara is here succeeded by a ledge of Devonian limestone, fifty feet in height. On account of the excellent exposure of Devonian strata overlying the Niagara at this place, a detailed description of the outcrop will be given under the discussion of the Devonian deposits.

A bed of impure dolomite, ten feet in thickness, is exposed along the banks of Otter creek, near Oelwein, in the northeast ¼ of section 29, Jefferson township. The ledge shows imperfect lines of bedding. It is quite vesicular. In places it contains an admixture of sand and carries a number of small calcite geodes. The following fossils were collected from these layers, *Zaphrentis stokesi* Ed. & H., *Favosites favosus* Goldfuss, *Halysites catenulatus* Linn., Syringopora sp., and casts of small individuals of *Pentamerus oblongus* Sowerby.

Two miles north of the town of Fairbank, near the southwest corner of section 20, Oran Township, a bluff of dolomite borders the east bank of a branch of the Wapsipinicon river for a distance of several rods. The exposure here shows the following layers:

		FEET.
5.	Bed of moderately coarse sand	4½
4.	Gravels, which are in places much iron-stained	3½
3.	Residual material of a much weathered bed of dolomite, containing *Favosites favosus*, *Halysites catenulatus*, *Lyellia americana* and *Alveolites undosus*	2
2.	Ledge of coarse-grained, yellowish-brown dolomite, which weathers into layers three to six inches in thickness, and contains fossils similar to number 3 above	7
1.	Massive ledge of yellow dolomite, coarse-grained in texture, carrying nodules of chert, and containing *Favosites favosus*, *Halysites catenulatus*, Syringopora sp. and *Lyellia americana*	8

Materials which correspond with those of the above section outcrop along the south bank of a small stream, about one mile northeast of Fairbank, on land owned by Mr. Oscar Constantine. Imperfect exposures of weathered Niagara materials of this same horizon are encountered at a number of points along the streams in sections 16, 20 and 21 of Oran township.

The rocks in the above mentioned exposures, near Fairbank, are quite similar in their lithological characters and their contained fossils to those of the exposure near Oelwein. They also resemble quite closely those of members 1 to 5 of the Niagara-Devonian Contact exposure in section 5 of Westfield township, and those of the upper Niagara layers at Westfield bridge. It seems probable that the materials in each of these exposures belong to horizons that are separated by no great thickness of strata; and that they represent deposits near the top of the Delaware stage, as the rocks of that stage are developed near the western margin of the Niagara area in Fayette county.

The Niagara outcrop north of Fairbank is especially interesting from the fact that in the town of Fairbank Devonian strata that lie just below the zone of *Acervularia profunda* Hall and *Newberria johannis* Hall, nearly sixty feet above the base of the Devonian, are quarried at an altitude forty feet lower than the top of the Niagara bluff two miles further north. The presence of a fold of no mean proportions would seem to be indicated in this portion of the Niagara strata.

Near the middle of the east side of section 13, Smithfield township, the slopes and crest of a hill are strewn with masses of quartz which contain silicified coralla of *Favosites favosus* Goldfuss, and numerous casts and moulds of very large individuals of *Pentamerus oblongus* Sowerby. The immediate banks of this stream are bordered by low ledges of yellow dolomite which contain *Favosites favosus*, *Halysites catenulatus* and casts of a few small individuals of *Pentamerus oblongus*.

In the northeast ¼ of section 13 and the southeast ¼ of section 12 of the same township, a bed of buff colored dolomite outcrops to a height of twelve feet along the banks of a small creek. The ledge is massive and vesicular. It carries chert nodules, and contains *Favosites favosus*, *Halysites catenulatus* and

Syringopora tenella. In the residual chert masses scattered over the slope, above the ledge, there also occur numerous very large casts of *Pentamerus oblongus.*

The Niagara strata of our area probably attain their greatest thickness in the southeastern portion of the county. The presence in abundance, of casts of large individuals of *Pentamerus oblongus* in the residual chert masses that are scattered over the slopes, in Smithfield township, and the absence of such remains in the Niagara deposits of the central and northern portions of the county, would indicate that the Niagara strata of Fayette county belong to a horizon below the true *Pentamerus oblongus* zone. It seems probable that the materials of the *Pentamerus oblongus* horizon were once the uppermost deposits over only the southeastern portion of the area, and that they have subsequently been removed by the agents of denudation. If this inference is correct, the uppermost deposits of the Delaware stage in Fayette county belong to a horizon more than one hundred feet below the latest of the Niagara deposits that appear in the county of Delaware. There are indications, too, that the lower layers of the Niagara in our area correspond with layers which, in Delaware county, occupy a position several feet above the base of the Delaware stage. In short, it is probable that both the uppermost strata and the lowermost members of the Niagara beds, which are encountered in Delaware county, fade out towards the northwest, in the county of Fayette.

Devonian System.

WAPSIPINICON STAGE.

Deposits representing the Middle Devonian series immediately underlie the superficial materials over the central and western portions of our area, covering nearly one-half of the surface of Fayette county. These rocks belong to the two lowermost stages of the series, the Wapsipinicon and the Cedar

Valley. The strata range from the base of the fine-grained, delicately laminated bed, underlying the Lower Davenport phase of the Fayette breccia, to the layers containing very numerous individuals of *Dielasma iowensis* and *Athyris vittata*, which occur in a zone a few feet above the Acervularia coral reef.

Devonian rocks outcrop in the towns of Fayette and West Union, and they may be seen at several points between these places. They are exposed at a distance of two and one-half miles northeast of West Union. They are encountered in the banks of the streams along the north side of Windsor township. They appear at different points along Crane creek, down to within less than one mile of its junction with the Little Turkey river. Layers which belong to a horizon a few feet below the *Acervularia profunda* zone are exposed at a number of places in the vicinity of Waucoma.

Over the greater portion of the western tier of townships the mantle of drift is so deep that the indurated rocks appear at the surface at but a few points in Eden township in the extreme north, and Oran township in the south. Devonian strata belonging to a zone immediately below that of *Newberria johannis* are quarried in the town of Fairbank. Corresponding layers outcrop near the cemetery about three-fourths of a mile northwest of this point. Rocks belonging to the horizon of *Acervularia profunda* and *Newberria johannis* may be studied along the banks of the Volga river in the town of Maynard, and for a distance of more than one mile both north and south of this place. The Lower Davenport beds of the Wapsipinicon stage outcrop in the banks of Alexander creek, near the northeast corner of section 5, Smithfield township, and this phase is exceptionally well exposed in the vicinity of the town of Fayette.

Just north of Westfield bridge, in the northeast ¼ of section 29, the lower members of the Devonian can be well studied in their relation to the underlying strata of the Delaware stage. The section below the surface materials is as follows:

FEET.

9. Decayed zone composed of thin fragments, which in places are crowded with valves of *Newberria johannis*, weathered individuals of *Acervularia profunda*, *Cystiphyllum americanum*, *Cladopora iowensis* and Favosites sp. occur in the upper part.. 1
8. Bed consisting of yellow, fine-grained, impure limestone, in layers two to six or eight inches in thickness. The layers are somewhat broken, and contain the fossils *Atrypa reticularis* and *A. aspera* var. *occidentalis*. Small cavities lined with crystals of calcite are not rare.............. 5½
7. Bed of yellow colored, impure limestone, in three layers respectively two and three-fourths, two and one-fourth and two feet in thickness. Besides the fossils of number 8, *Pentamerella dubia* and *Spirifer pennatus* occur in the lower layer.. 7
6. Bed of rather massive, yellowish-gray limestone, less magnesian than the layers of number 7 above, somewhat broken, but the large fragments lie in the general plane of the original layers; containing in the upper portion Favosites sp., *Pentamerella dubia*, *Gypidula comis*, *Spirifer pennatus*, *Atrypa reticularis*, *A. aspera* var. *occidentalis* and *Hypothyris intermedia*...................... 8
5. Bed of light colored, argillaceous limestone, with few fossils; consisting of brecciated material in which small limestone fragments are imbedded in an abundant matrix of clayey shale 7
4. Bed of Lower Davenport breccia; composed of dense, fine-grained, drab colored fragments of limestone, surrounded with lighter colored cementing material; without fossils 10
3. Bed of yellowish-gray limestone, very fine-grained; exposed surfaces showing numerous, delicate lines of lamination; weathering in thin fragments which are characteristic of this zone; no fossils... 11
2. Bed consisting of two imperfect layers of yellow, magnesian limestone, one foot and two feet in thickness; the upper one dense and rather fine-grained, the lower vesicular and somewhat softer; without fossils.......................... 3
1. Bed of yellowish, magnesian limestone, in layers which are respectively two, four, two and one-third, one, two, four, two and one-half, and five feet in thickness. Small cavities are numerous, and nodules of chert abundant; containing *Lyellia americana*, *Favosites favosus*, *Halysites catenulatus* and other fossils.................... 22

This exceedingly instructive section may be designated as that of the Westfield Bridge. Not only is the contact of the Niagara and the Devonian well shown at this place, but there is also exposed an almost complete section of the Devonian strata as those deposits are developed in this portion of the state. See figure 45.

FIG. 45. Exposure at Westfield bridge in the town of Fayette, showing the contact of the Niagara and Devonian limestones. The layer marked A, a short distance below the middle of the picture, is the uppermost layer of the Niagara at this place.

The dolomite layers of number 1, containing *Lyellia americana*, *Favosites favosus*, *F. niagarensis*, *Halysites catenulatus*, *Leptæna rhomboidalis* and a species of Orthis, are readily recognized as belonging to the Delaware stage. Number 2 also belongs with this Niagara bed. These layers are the equivalent of numbers 1 to 5 inclusive of the Niagara-Devonian Contact section, three and one-half miles further north.

Number 3 represents the basal member of the Wapsipinicon stage, and corresponds with number 6 of the Niagara-Devonian Contact section above mentioned. This bed of yellow colored, fine-grained material, in which very numerous, delicate lines of lamination are preserved, and which weathers into thin, fissile fragments, is uniformly present as the lowermost member of the Devonian in Fayette county. The line between numbers 2 and 3 of the Westfield Bridge section, which separates the Devonian strata from the Niagara beds, is well exposed for a distance of several rods but there is shown no decided evidence of unconformity between these deposits. Number 4 is a bed of the typical Lower Davenport phase of Fayette breccia, and it is the equivalent of number 7 of the Contact exposure in section 5. The fragments are slate colored, fine-grained and very hard. They are usually small, rarely more than six inches in diameter. The lighter colored cementing material or matrix composes about one-half of the constituents of the bed. No fossils were found in this member. It is probable that number 5 represents a slightly unusual phase of development of the Lower Davenport beds in which light colored, indurated, clay-like shale predominates over the general brecciated materials. Number 6 is composed of a massive, slightly fractured ledge of gray, fossiliferous limestone, rather similar throughout. It shows lines of bedding which separate the ledge into indistinct layers two to two and one-half feet in thickness. This member contains *Pentamerella dubia* Hall, *Gypidula comis* Owen, *Hypothyris intermedia* Barris, *Spirifer pennatus* Owen, *Atrypa reticularis* Linn. and *A. aspera* var. *occidentalis* Hall. These fossils are characteristic of the Gyroceras beds, as defined by Professor Calvin* in Buchanan county, and of the Upper Davenport beds of Professor Norton,† as described in the Linn county report.

The materials of number 7 and 8 are quite similar in color and lithology to those of number 6, but the thickness of the layers constantly decreases towards the top. In number 8 the layers are considerably shattered although the fragments are not displaced. Small veins and geodes of calcite are abundant.

* Calvin: Iowa Geol. Surv., Vol. VIII, pp. 225 *et seq.*

†Norton: Iowa Geol, Surv., Vol. IV, pp. 157 *et seq.*

Number 9 is composed largely of calcareous layers that are filled with more or less broken valves of *Newberria johannis*, and which are overlain by residual fragments and weathered coralla from the zone of *Acervularia profunda*. A few rods further down the river there is exposed at the top of the bluff a thickness of four feet above the *Newberria johannis* horizon. These layers contain coralla of *Acervularia profunda* Hall in place, together with Cyathophyllum sp., *Cladopora iowensis* Hall and

FIG. 46. Cut along the Chicago, Milwaukee & Saint Paul railroad, a short distance west of station, Fayette, Iowa. The walls of the cut are Devonian limestone and the track is laid on the Niagara.

colonies of Favosites resembling *F. placenta* Rominger. This is the typical *Acervularia profunda* zone in its normal position, only a very short distance above that of *Newberria johannis*.

An exposure which is almost a duplicate of that at Westfield bridge appears in the south bank of the Volga river, near the middle of the south side of section 21, Westfield township. At

this place a quarry is worked in the yellow, somewhat disturbed layers corresponding with the upper part of number 6 and numbers 7 and 8 of the Westfield Bridge section. Several small quarries are worked in the layers of this horizon within the limits of the town of Fayette.

The contact of the Niagara and Devonian strata is again well shown in the northwest ¼ of section 17, Union township. A quarry has been opened in this ledge, within the corporate limits of West Union, which is operated by the city for crushed stone. At this place a thickness of about one and one-half feet of Niagara dolomite appears at the base of the exposure. This is succeeded by a bed of yellowish, fine-grained material, ten feet in thickness, which shows very numerous, fine lines of lamination, and which weathers into thin fragments. This latter bed corresponds with number 3 of the Westfield Bridge section. Above this fine-grained, delicately laminated bed there occurs a thickness of about six feet of the typical Lower Davenport breccia.

An interesting section of the Wapsipinicon strata of our area is exposed in the deep cut along the Chicago, Milwaukee & Saint Paul railway, a few rods west of the station at Fayette. The strata at this place are shown in figure 46. The cut is fifty feet in depth and six hundred feet long. There appears in either wall the following succession of layers:

		FEET.
6.	Bed consisting of somewhat shattered layers of fine-grained, yellow colored, impure limestone, three to nine inches in thickness; containing *Atrypa reticularis* and *A. aspera* var. *occidentalis*	11½
5.	Bed composed of yellow colored, magnesian limestone, similar in lithology to number 6 above, in imperfect layers one and one-half to three feet in thickness; containing *Gypidula comis*, *Spirifer pennatus* and the Atrypas	8½

	FEET.
4. Thick layers of gray limestone, somewhat fractured, yet not so thoroughly brecciated but that the original layers can be recognized. The large fragments contain *Favosites placenta*, *Stropheodonta demissa*, *Pholidostrophia nacrea*, *Productella subalata*, *Orthis iowensis*, *Gypidula comis*, *Spirifer pennatus*, *Atrypa reticularis*, *A. aspera* var. *occidentalis*, *Athyris vittata* and tritors of *Ptyctodus calceolus*	10
3. Bed of yellowish colored, calcareous shale; quite indurated; showing scant traces of brecciation; without fossils	6
2. Bed composed of slate-colored fragments of very hard, fine-grained limestone, imbedded in a matrix of fine-grained calcareous material which is lighter in color. Many of the fragments show delicate, closely crowded lines of lamination; no fossils......	11
1. Ledge of yellow colored, fine-grained limestone, on the face of which delicate, closely placed laminæ weather out in faint relief. Small fragments of the material present this characteristic laminated appearance. When long exposed to weathering the rock splits along these lines into thin bits............................	10

Number 1 of the foregoing section represents the basal member of the Wapsipinicon deposits, and corresponds with number 3 of the Westfield Bridge section. The rock is homogeneous, and fine-grained in texture. In some places it has been more or less brecciated as appears in the fact that there are occasional areas in which groups of closely crowded, delicate laminæ, which are usually parallel with the planes of bedding, lie at various angles with respect to one another and to the larger planes of stratification. In other places the fine lines of lamination are gently undulating or slightly faulted. Numerous thin veins of calcite indicate the position of the original lines of fracture. Aside from such calcite veins there appears no other cementing material. The upper portion of this bed shows slight flexures, the arches of the folds having, in some places, a height of one to one and one-half feet. The material appears to have been of a slaty color before it was acted upon by the atmosphere. Upon weathering it is changed to a yellow color, and breaks along the lamination planes into charac-

teristic thin, fissile bits. The materials of this member are less resistant than those of the overlying Lower Davenport breccia, number 2 of the section, as appears in the relative amount of the fragments of each member in the talus heap at the foot of the ledge. This is also indicated by the fact that the rock of the first member has crumbled down to such an extent as to leave a shelf of the materials of number 2 projecting beyond the lower member for a distance of one and one-half feet.

The lithological characters and general appearance of the material of this basal member of the Devonian limestone in Fayette county, number 1 of the last section, would ally it very closely with the Otis beds as described by Norton.* Because of the thinness of the formation in our area, and on account of the fact that it presents occasional brecciated masses this member will be included as the basal portion of the Fayette breccia.

At a few places in the cut there is exposed below number 1 a thickness of one to one and one-half feet of yellowish-colored dolomite. This material represents the Niagara limestone, and corresponds with the uppermost layer of the Niagara at Westfield bridge, less than one mile to the north. Both in the cut and at the Westfield Bridge exposure such dolomite is succeeded by a bed of fine-grained, closely laminated limestone, as number 1 described above. In the railroad cut, the top of the Niagara limestone forms the floor upon which the track is laid.

The respective beds that succeed number 1 in the last section are readily correlated with, and their development is not unlike, those that lie above number 3 in the Westfield Bridge section. Numbers 4 and 5 consist of limestone that shows no trace of dolomitization. It is somewhat fractured, but the thick layers have not been greatly disturbed. The fossils found in this member include *Pholidostrophia nacrea* Hall, *Productella subalata* Hall, *Orthis macfarlanei* Meek, *Pentamerella dubia* Hall, *Gypidula laeviuscula* Hall, *Gypidula comis* Owen, *Hypothyris intermedia* Barris. *Atrypa reticularis* Linn., *A. aspera* var., *occidentalis* Hall, *Spirifer pennatus* Owen, and *Athyris vittata* Hall.

*Norton: Iowa Geol. Surv., Vol. IV, p. 138, *et seq.* 1894.

An exposure of brecciated limestone which corresponds with numbers 2 to 4 inclusive of the section of the Railroad Cut can be seen in the east bank of Alexander creek, near the southeast corner of section 32, Westfield township. In walking up the bed of a ravine that crosses the wagon road a few rods west of this point the breccia of this same horizon is passed over, and the succeeding beds of less shattered, thicker limestone layers are encountered which contain *Orthis iowensis* Hall, *Gypidula comis* Owen, *Atrypa reticularis* Linn. and *A. aspera* var. *occidentalis* Hall, and which belong to the Upper Davenport phase of the breccia.

In the northwest ¼ of section 6, Windsor township, the following succession of layers is exposed in the east bank of a small stream:

		FEET.
6.	Bed of residual materials, containing weathered remains of Cyathophyllum sp., *Acervularia profunda*, *Cystiphyllum americanum*, Favosites sp., *Spirifer pennatus* and *Atrypa reticularis*...	1
5.	Bed composed of layers of yellow, magnesian limestone, two to six inches in thickness. The layers are much checked and broken, and contain few traces of fossils..........	6
4.	Bed of yellow, fine-grained, earthy limestone, in layers six to twenty-four inches in thickness. The materials are more or less shattered, and show numerous small spherical patches in which iron-stained lines are concentrically arranged about a common center..........	3½
3.	Ledge of yellow, impure limestone, resembling that of number 4 above, in layers eight to thirty inches in thickness; containing imperfectly preserved fragments of brachiopod shells..........	6
2.	Bed of yellowish-gray limestone, in rather indistinct layers which are checked with numerous joints; containing *Productella subalata*, *Pentamerella dubia*, *Gypidula comis*, *Spirifer pennatus*, *Atrypa reticularis* and *A. aspera* var. *occidentalis*	8
1.	Bed composed largely of light colored shale, in which a few irregular fragments of limestone are imbedded. Such fragments become more abundant in the lower part; talus covered to bed of stream..........	7

In the above, which may be known as the Windsor section, number 1 corresponds with number 3 of the Railroad Cut section and with number 5 of that of Westfield Bridge. Number 2 above is a well marked zone which is characterized by the fossils *Productella subalata* Hall, *Pentamerella dubia* Hall, *Gypidula comis* Owen, *Atrypa reticularis* Linn., *A. aspera* var. *occidentalis* Hall, and *Spirifer pennatus* Owen. This bed is the equivalent of number 4 of the Cut, and of number 6 of the

FIG. 47. Ledge of Cedar Valley limestone near the northwest corner of section 2, Bethel township. The horizon of *Acervularia profunda* occurs at the top, and *Spirifer pennatus* is found in the heavy layers at the base. The stone is magnesian throughout.

Westfield Bridge section. Number 6 of the last section represents the horizon of number 9 at Westfield bridge.

Rocks which correspond with those of numbers 2 to 5 inclusive of the last section outcrop about forty rods southwest of this exposure, and they may be seen on either side of the wagon road as it turns east in the southwest ¼ of section 6 of Windsor township.

Near the middle of the west side of section 35 of Eden township, there outcrops in the north bank of Crane creek a cliff of Devonian limestone thirty-five feet in height. The beds exposed here are embraced between the *Acervularia profunda* zone at the top and the Lower Davenport breccia at the base.

In the extreme northwest corner of section 2 of Bethel township, a representative section of the uppermost Devonian beds appears in the east bank of a small affluent about one-half mile above its junction with Crane creek. The rocks in this exposure are shown in figure 47, and the section is as follows:

		FEET.
5.	Bed of yellow colored, fine-grained, dolomite in broken layers three to eight inches in thickness. In the upper part the fossils *Acervularia profunda*, *Cystiphyllum americanum*, Favosites sp. and *Cladopora iowensis* are not rare............	8
4	Bed of fine-grained, yellow dolomite, in two layers which are somewhat broken, and contain no fossils..	1
3.	Ledge consisting of two layers of fine-grained, magnesian limestone, each about eight inches in thickness. The material is yellow in color and quite durable. Small cavities lined with crystals of calcite are abundant.........................	1½
2.	Bed of dense, yellow colored, fine-grained, earthy limestone, in three layers which are respectively twenty-four, twenty and twenty-five inches in thickness; containing the fossils *Spirifer pennatus*, *S. bimesialis*, *Atrypa reticularis* and *A. aspera* var. *occidentalis*......	5¾
1.	In the bed of the stream, a few rods below the exposure of the members 2 to 5 inclusive, there are encountered heavy layers of yellow dolomite which underlie the base of number 2, and contain *Stropheodonta demissa*, *Productella subalata*, *Pentamerella dubia*, *Gypidula comis*, *Spirifer pennatus*, *Cyrtina hamiltonensis*, *Atrypa reticularis* and *A. aspera* var *occidentalis*......	6

teristic thin, fissile bits. The materials of this member are less resistant than those of the overlying Lower Davenport breccia, number 2 of the section, as appears in the relative amount of the fragments of each member in the talus heap at the foot of the ledge. This is also indicated by the fact that the rock of the first member has crumbled down to such an extent as to leave a shelf of the materials of number 2 projecting beyond the lower member for a distance of one and one-half feet.

The lithological characters and general appearance of the material of this basal member of the Devonian limestone in Fayette county, number 1 of the last section, would ally it very closely with the Otis beds as described by Norton.* Because of the thinness of the formation in our area, and on account of the fact that it presents occasional brecciated masses this member will be included as the basal portion of the Fayette breccia.

At a few places in the cut there is exposed below number 1 a thickness of one to one and one-half feet of yellowish-colored dolomite. This material represents the Niagara limestone, and corresponds with the uppermost layer of the Niagara at Westfield bridge, less than one mile to the north. Both in the cut and at the Westfield Bridge exposure such dolomite is succeeded by a bed of fine-grained, closely laminated limestone, as number 1 described above. In the railroad cut, the top of the Niagara limestone forms the floor upon which the track is laid.

The respective beds that succeed number 1 in the last section are readily correlated with, and their development is not unlike, those that lie above number 3 in the Westfield Bridge section. Numbers 4 and 5 consist of limestone that shows no trace of dolomitization. It is somewhat fractured, but the thick layers have not been greatly disturbed. The fossils found in this member include *Pholidostrophia nacrea* Hall, *Productella subalata* Hall, *Orthis macfarlanei* Meek, *Pentamerella dubia* Hall, *Gypidula laeviuscula* Hall, *Gypidula comis* Owen, *Hypothyris intermedia* Barris. *Atrypa reticularis* Linn., *A. aspera* var., *occidentalis* Hall, *Spirifer pennatus* Owen, and *Athyris vittata* Hall.

*Norton: Iowa Geol. Surv., Vol. IV, p. 138, *et seq.* 1894.

An exposure of brecciated limestone which corresponds with numbers 2 to 4 inclusive of the section of the Railroad Cut can be seen in the east bank of Alexander creek, near the southeast corner of section 32, Westfield township. In walking up the bed of a ravine that crosses the wagon road a few rods west of this point the breccia of this same horizon is passed over, and the succeeding beds of less shattered, thicker limestone layers are encountered which contain *Orthis iowensis* Hall, *Gypidula comis* Owen, *Atrypa reticularis* Linn. and *A. aspera* var. *occidentalis* Hall, and which belong to the Upper Davenport phase of the breccia.

In the northwest ¼ of section 6, Windsor township, the following succession of layers is exposed in the east bank of a small stream:

		FEET.
6.	Bed of residual materials, containing weathered remains of Cyathophyllum sp., *Acervularia profunda*, *Cystiphyllum americanum*, Favosites sp., *Spirifer pennatus* and *Atrypa reticularis*...	1
5.	Bed composed of layers of yellow, magnesian limestone, two to six inches in thickness. The layers are much checked and broken, and contain few traces of fossils............................	6
4.	Bed of yellow, fine-grained, earthy limestone, in layers six to twenty-four inches in thickness. The materials are more or less shattered, and show numerous small spherical patches in which iron-stained lines are concentrically arranged about a common center.................	3½
3.	Ledge of yellow, impure limestone, resembling that of number 4 above, in layers eight to thirty inches in thickness; containing imperfectly preserved fragments of brachiopod shells..........	6
2.	Bed of yellowish-gray limestone, in rather indistinct layers which are checked with numerous joints; containing *Productella subalata*, *Pentamerella dubia*, *Gypidula comis*, *Spirifer pennatus*, *Atrypa reticularis* and *A. aspera* var. *occidentalis*	8
1.	Bed composed largely of light colored shale, in which a few irregular fragments of limestone are imbedded. Such fragments become more abundant in the lower part; talus covered to bed of stream.............	7

In the above, which may be known as the Windsor section, number 1 corresponds with number 3 of the Railroad Cut section and with number 5 of that of Westfield Bridge. Number 2 above is a well marked zone which is characterized by the fossils *Productella subalata* Hall, *Pentamerella dubia* Hall, *Gypidula comis* Owen, *Atrypa reticularis* Linn., *A. aspera* var. *occidentalis* Hall, and *Spirifer pennatus* Owen. This bed is the equivalent of number 4 of the Cut, and of number 6 of the

FIG. 67. Ledge of Cedar Valley limestone near the northwest corner of section 2, Bethel township. The horizon of *Acervularia profunda* occurs at the top, and *Spirifer pennatus* is found in the heavy layers at the base. The stone is magnesian throughout.

Westfield Bridge section. Number 6 of the last section represents the horizon of number 9 at Westfield bridge.

Rocks which correspond with those of numbers 2 to 5 inclusive of the last section outcrop about forty rods southwest of this exposure, and they may be seen on either side of the wagon road as it turns east in the southwest ¼ of section 6 of Windsor township.

Near the middle of the west side of section 35 of Eden township, there outcrops in the north bank of Crane creek a cliff of Devonian limestone thirty-five feet in height. The beds exposed here are embraced between the *Acervularia profunda* zone at the top and the Lower Davenport breccia at the base.

In the extreme northwest corner of section 2 of Bethel township, a representative section of the uppermost Devonian beds appears in the east bank of a small affluent about one-half mile above its junction with Crane creek. The rocks in this exposure are shown in figure 47, and the section is as follows:

		FEET.
5.	Bed of yellow colored, fine-grained, dolomite in broken layers three to eight inches in thickness. In the upper part the fossils *Acervularia profunda*, *Cystiphyllum americanum*, Favosites sp. and *Cladopora iowensis* are not rare............	8
4	Bed of fine-grained, yellow dolomite, in two layers which are somewhat broken, and contain no fossils..	1
3.	Ledge consisting of two layers of fine-grained, magnesian limestone, each about eight inches in thickness. The material is yellow in color and quite durable. Small cavities lined with crystals of calcite are abundant.........................	1⅓
2.	Bed of dense, yellow colored, fine-grained, earthy limestone, in three layers which are respectively twenty-four, twenty and twenty-five inches in thickness; containing the fossils *Spirifer pennatus*, *S. bimesialis*, *Atrypa reticularis* and *A. aspera* var. *occidentalis*......	5¾
1.	In the bed of the stream, a few rods below the exposure of the members 2 to 5 inclusive, there are encountered heavy layers of yellow dolomite which underlie the base of number 2, and contain *Stropheodonta demissa*, *Productella subalata*, *Pentamerella dubia*, *Gypidula comis*, *Spirifer pennatus*, *Cyrtina hamiltonensis*, *Atrypa reticularis* and *A. aspera* var *occidentalis*......	6

In the foregoing section number 1 corresponds with number 2 of the Windsor section, with number 4 in that of the Railroad Cut at Fayette, and with number 6 of the Westfield Bridge section. This member is well developed in the northwestern portion of the county where the materials of the Devonian are almost universally dolomitized. This bed is the lowermost of the Devonian deposits that was seen in Eden township, with the exception of a single exposure near the southeast corner. It contains *Stropheodonta demissa* Conrad, *Productella subalata* Hall, *Pentamerella dubia* Hall, *Gypidula comis* Owen, *Spirifer pennatus* Owen, *Cyrtina hamiltonensis* Hall, *Atrypa reticularis* Linn. and *A. aspera* var. *occidentalis* Hall. The assemblage of fossils is characteristic of the Upper Davenport beds, which constitute the uppermost deposits of the Wapsipinicon stage. Number 2 above is the equivalent of number 5 of the Fayette Cut section and with number 7 of the section at Westfield bridge. The rocks of the members 3 to 5 of the foregoing section succeed those of number 2 in the normal order in which they appear above the correlative of that member in the sections of the Fayette Cut and Westfield Bridge.

In Howard county, beds that are the equivalent of numbers 1 to 3 of the above section are the lowermost strata of the Devonian that are present,* and they rest directly upon the shales of the Maquoketa stage. All of the Lower Davenport phase of the Fayette breccia, as well as the bed of fine-grained, finely laminated material that underlies it in the central portion of Fayette county, fade out completely a few miles further towards the northwest.

The materials of the first three members of the last section may probably be correlated with the lowermost strata that appear in Chickasaw county.† They correspond with the layers that are exposed in the quarries near Independence, in Buchanan county, and they are the equivalent of the beds that appear in the railroad cut three miles northwest of Vinton, in Benton county. At the latter place the deposits of this horizon have a thickness very much greater than they attain in the county of Fayette.

*Calvin: Iowa Geol. Surv., Vol. XIII, p. 50. *et seq.*

†Calvin: Iowa Geol. Surv., XIII, p. 268. *et seq.*

Layers of yellow, impure dolomite, which correspond with numbers 2 to 4 of the last section, are quarried about one-half mile north of the village of Alpha, in Eden township, on land owned by Mr. Seth Clark. They also outcrop a short distance west of this place, on land belonging to Mr. Hilton.

About one-half mile northwest of Waucoma, a quarry is operated in a body of massive, earthy dolomite which is overlain by somewhat broken layers, four to eight inches in thickness. The rock is yellow and quite vesicular. In the thick ledge at the base the bedding planes have been so completely destroyed in the process of dolomitization that masses are quarried out without any regard to the original lines of stratification. *Acervularia profunda* was found in the upper layers, and casts of *Productella subalata* Hall, *Gypidula comis* Owen, *Spirifer pennatus* Owen, a species of Spirifer resembling *S. bimesialis* Hall, *Atrypa reticularis* Linn. and *A. aspera* var. *occidentalis* Hall were collected from the massive bed at the base. The rocks that are exposed in this quarry correspond with the layers that are worked in the vicinity of Alpha.

Broken layers which contain colonies of *Acervularia profunda* and shells of *Atrypa reticularis* outcrop in the wagon road, near the middle of the north side of section 5 of Eden township, and they appear again in the banks of a small stream some rods further east.

CEDAR VALLEY STAGE.

The line which separates the deposits of the Wapsipinicon stage from those of the Cedar Valley has been somewhat arbitrarily drawn between the *Spirifer pennatus* beds and the overlying layers which contain *Acervularia profunda* and several other species of corals. In Fayette county the *Spirifer pennatus* horizon can not be perfectly differentiated from that of the Gyroceras beds which precede it. The Cedar Valley strata will be considered to start with the undisturbed layers a short distance below the *Acervularia profunda* and *Newberria johannis* zone. At no place in the county have these beds been involved in the brecciation or disturbance that so profoundly affected the most of the strata of the Wapsipinicon stage.

As thus delimited, the uppermost layers that appear at Westfield bridge, which contain many corals and numerous detached valves of *Newberria johannis*, represent the basal portion of the Cedar Valley deposits.

In the town of Fairbank a quarry is worked in the west bank of the river, just south of the Catholic school. The following layers are here shown:

		FEET
5.	Iron-stained gravels with a dark colored soil zone at the top; containing numerous weathered corralla of *Acervularia davidsoni*, *Cystiphyllum americanum*, *Favosites alpenensis* and other species of corals	5
4.	Bed of yellow, much decayed limestone, in thin layers, which contain species of Cyathophyllum, Cystiphyllum and Favosites, and a few individuals of *Newberria johannis* that have weathered out entire	2½
3.	Bed composed of thin layers of hard, gray limestone which in places are crowded with detached valves of *Newberria johannis*	2
2.	Yellowish-gray limestone in rather even layers with occasional bands of softer, shaly material; showing numerous spots of concentrically arranged lines of iron stains; containing Cyathophyllum, Cystiphyllum, Favosites, and occasional shells of *Stropheodonta demissa*.	6
1.	Massive bed of gray limestone; containing numerous geodes of calcite, and bearing but few fossils	3

The above section represents a slightly greater development of the *Newberria johannis* beds than appears in the exposures further north. *Acervularia profunda* is usually found in the layers which correspond with those of 2 to 4 of the foregoing section. The spherical, iron-stained concretions are generally abundant in the zone immediately preceding that of *Newberria johannis*, and cavities lined with crystals of calcite are abundant in layers corresponding with number 1 of the last section.

About one-half mile northwest of Fairbank a quarry was formerly worked near the Catholic cemetery. The layers that are seen at this place are the equivalent of numbers 1 to 3 of the Fairbank section. At the top there appear thin layers that are

largely composed of broken or detached valves of *Newberria johannis*. Below this zone are seen the yellow layers with concentric iron stains. This lower bed contains occasional remains of *Cystiphyllum americanum*, *Stropheodonta demissa* and *Atrypa reticularis;* and carries small geodes of calcite. These layers show no traces of brecciation or dolomitization, and they represent a horizon at the base of the Cedar Valley deposits.

Along the Volga river in the east part of Maynard, the following layers are exposed:

		FEET.
4.	Reddish-brown sand and fine gravel	1½
3.	Zone of decayed limestone, in which occur numerous coralla of Cyathophyllum sp., *Acervularia profunda*, *Cystiphyllum americanum*, *Heliophyllum halli*, Favosites sp. and Syringopora sp	2
2.	Bed consisting of thin layers of gray limestone, some of which are composed almost wholly of valves of *Newberria johannis*. *Acervularia profunda*, *Cystiphyllum americanum* and other corals are present	4
1.	Bed of gray limestone in layers three to eight inches in thickness; containing *Acervularia profunda*, *Alveolites goldfussi*, Stromatopora sp., *Stropheodonta demissa*, *Spirifer pennatus*, *S. fimbriatus*, and finely-striated, Independence forms of *Atrypa reticularis*	6

In the above section number 3 is distinctly a coral zone that succeeds the horizon of *Newberria johannis*. The Newberria layers also contain a few corals. The first member contains numerous brachiopod shells which are usually associated with the corals in the layers below the Newberria zone.

Some rods south of the Maynard exposure there may be seen, in the bed of the river, undisturbed masses of gray limestone in which both large and small individuals of *Gypidula comis* are exceedingly abundant. These rocks also contain occasional colonies of *Acervularia profunda* Hall, *Favosites placenta* Rom., *Productella subalata* Hall, *Orthis iowensis* Hall, *Dielasma roemingeri* Hall, *Spirifer pennatus* Owen, *S. bimesialis* Hall, *Cyrtina hamiltonensis* Hall, Independence forms of *Atrypa reticularis*, Linn., *A. aspera* var. *occidentalis* Hall, and *Phacops rana* Green.

The layers of the Maynard section belong to a horizon that corresponds very closely with that of the Devonian beds exposed in the vicinity of Fairbank. The fauna seen in the layers along the bed of the river some distance south of Maynard would indicate a zone just below the base of the Cedar Valley stage.

For a distance of one mile north of Maynard there are exposed, in every bend of the river, limestone layers that are included between the Newberria zone at the top and the horizon of very abundant shells of *Gypidula comis* at the base. Beautiful coralla of *Acervularia profunda* have weathered out along this portion of the river's channel. Beds which belong to this horizon appear again at the iron bridge, three miles north of Maynard. About four miles still further down the Volga river, at Eagle Point, the equivalents of these layers appear near the top of the bluff sixty feet above the water, and almost the entire section of the Wapsipinicon strata is exposed below them. See figure 33 on page 446.

Near the extreme southwest corner of section 18 of Westfield township, there outcrops a low, weathered ledge of limestone that contains *Acervularia profunda* Hall, *Stropheodonta demissa* Conrad, *Orthis iowensis* Hall, *Dielasma rœmingeri* Hall, *Spirifer pennatus* Owen, *Atrypa reticularis* Linn. and *A. aspera* var. *occidentalis* Hall. Continuing north up the hill, layers representing a horizon twelve to fifteen feet above this ledge are passed over. In these upper layers the form of *Atrypa reticularis* becomes more robust and more coarsely striated. *Spirifer pennatus* is still frequent, while *Dielasma iowensis* Calvin, and *Spirifer subvaricosus* H. & W. make their appearance. *Acervularia profunda* Hall, *A. davidsoni* Ed. & H., and *Favosites alpenensis* Winchell, are occasionally encountered. These fossils indicate a horizon near the base of the Cedar Valley deposits.

In the southwest ¼ of section 17 of Union township, the following layers are exposed in a small quarry on the north side of the railroad track:

	FEET.
4. Bed of sand or sandy loess, with a dark colored soil band at the top	5
3. Reddish-brown clay, containing gravel and small bowlders	3
2. Ledge of gray, weathered limestone, in rather irregular layers, which contain *Acervularia profunda*, *Phillipsastrea billingsi*, *Craspedophyllum strictum*, *Favosites alpenensis* and *Cladopora magna*	3
1. Bed consisting of layers of gray limestone three to twelve inches in thickness; containing *Stropheodonta demissa*, *Spirifer pennatus*, *S. subvaricosus*, *Atrypa reticularis* and *A. aspera* var. *occidentalis*	5

About thirty rods to the east of this exposure limestone layers corresponding with those of the above section are worked. There is here seen, below the horizon of number 1, a massive layer of gray limestone which contains numerous geodes of calcite and carries, in the middle portion, abundant shells of *Gypidula comis* and *Atrypa reticularis*.

In the foregoing section, numbers 1 and 2 doubtless represent the lowermost of the Cedar Valley strata, and they probably correspond with the Devonian layers exposed near Maynard and Fairbank. They contain a rich fauna which include Cyathophyllum sp., *Acervularia profunda* Hall, *Phillipsastrea billingsi* Calvin, *Craspedophyllum strictum* Ed. & H., *Heliophyllum halli* Ed. & H., *Cystiphyllum americanum* Ed. & H., *Cladopora magna* Hall, *Favosites placenta* Rominger, Favosites sp., Syringopora sp., *Stropheodonta demissa* Conrad, Stropheodonta sp., *Spirifer pennatus* Owen, *S. fimbriata* Morton, *S. subvaricosus* H. & W., *Cyrtina hamiltonensis* Hall, *Atrypa reticularis* Linn. and *A. aspera* var. *occidentalis* Hall.

At the top of the ledge in the upper railroad cut, in the northwest ¼ of section 30 of Westfield township, there occur numerous remains of corals which are distinctive of the *Acervularia profunda* horizon. In layers below the coral zone were collected *Pholidostrophia nacrea* Hall, Productella sp., *Orthis macfarlanei* Meek., *Gypidula læviuscula* Hall, *Gypidula comis* Owen, *Hypothyris intermedia* Barris, the Atrypas usually associated with these fossils and *Athyris vittata* Hall. Layers

of the coral zone are again encountered in the northeast ¼ of section 17, Westfield township, and they appear at other points in this and the adjoining township of Center.

Probably the uppermost Devonian layers that are exposed in Fayette county appear in an unused grade for a railroad that was projected some years ago between the towns of Lima and Sumner. This abandoned grade is crossed by the Chicago, Milwaukee & Saint Paul railway, in the southeast ¼ of section 13 of Center township. At this place the grade is about twelve feet in height. The materials of which it was built were taken from shallow excavations on either side of, and adjacent to, the ridge. The rock fragments that appear over the top and the sides of this grade are very fossiliferous. Many of the pieces of yellow limestone are crowded with shells of *Athyris vittata* Hall, and contain numerous individuals of *Dielasma iowenis* Calvin. At no other point in the state are these two species known to occur in such abundance.

Besides the above fossils there were found here *Favosites alpenensis* Winchell, Favosites sp., Syringopora sp., large individuals of *Stropheodonta demissa* Conrad, the large, coarse-ribbed form of *Atrypa reticularis* Linn., a species of Spirifer related to *S. pennatus* Owen, *S. subvaricosus* H. & W., *Cyrtina hamiltonensis* Hall, Gomphoceras sp. and individuals of a curved cephalopod resembling a species of Gyroceras.

The point where the old grade is crossed by the Milwaukee railway is about one and one-half miles northwest of the second railroad cut, referred to above, near the top of which the *Acervularia profunda* and the *Newberria johannis* zones are to be seen. It seems probable that the horizon of the very abundant *Athyris vittata* and *Dielasma iowensis* found on the abandoned grade is ten to fifteen feet above the zone of *Acervularia profunda*, and that the fragments which contain those fossils represent the uppermost layers of Cedar Valley limestone that occur in Fayette county.

A general section of the Devonian strata known to be exposed in Fayette county may be arranged as follows:

GENERAL DEVONIAN SECTION.

		FEET.
11.	Layers represented by the fragments which are found on the unused railroad grade, in the southeast ¼ of section 13 of Center township; containing rock masses crowded with shells of *Athyris vittata* and bearing numerous individuals of *Dielasma iowensis*, besides large individuals of *Stropheodonta demissa* and of the coarse-ribbed form of *Atrypa reticularis*.	12
10.	Coral zone made up of gray limestone which contains Cyathophyllum sp., *Acervularia profunda*, *Cystiphyllum americanum*, *Heliophyllum halli*, *Favosites alpenensis* and other species of corals	2½
9.	Bed consisting of thin layers of gray limestone, some of which are composed almost wholly of detached valves of *Newberria johannis*, also containing *Acervularia profunda*, *Cystiphyllum americanum* and *Cladopora magna*......	4
8.	Bed of gray limestone, in layers three to twelve inches in thickness; containing *Acervularia profunda*, *Alveolites goldfussi*, *Stropheodonta demissa*, *Spirifer pennatus*, *S. subvaricosus*, *S. fimbriatus*, *Atrypa aspera* var. *occidentalis* and *A. reticularis*	6
7.	Bed of limestone, in places dolomitic, in some places gray and in others yellow in color; containing very numerous individuals of *Gypidula comis*, also *Productella subalata*, *Orthis iowensis*, *Dielasma roemingeri*, *Spirifer pennatus*, *S. bimesialis*, *Cyrtina hamiltonensis*, Independence forms of *Atrypa reticularis* and *Phacops rana*............................	4½
6.	Bed made up of somewhat shattered layers of yellow colored, fine-grained, earthy limestone, three to nine inches in thickness; containing the species of Atrypa found in number 5. Small cavities lined with crystals of calcite are abundant in the upper portion...............	11½
5.	Bed of yellow, impure, magnesian limestone, rather fine-grained, in imperfect layers one and one-half to three feet in thickness; containing *Gypidula comis*, *Spirifer pennatus Atrypa reticularis* and *A. aspera* var. *occidentalis*....	8½

	FEET.
4. Bed of gray limestone, consisting of layers two to two and one-half feet in thickness; somewhat fractured but the masses not displaced to such an extent but that the layers can be recognized. The large fragments contain *Favosites placenta*, *Stropheodonta demissa*, *Pholidostrophia nacrea*, *Productella subalata*, *Orthis iowensis*, *Gypidula comis*, *Spirifer pennatus*, two species of Atrypa, *Athyris vittata* and tritors of *Ptyctodus calceolus*....................................	10
3. Bed of gray or yellowish colored, calcareous, shale; quite indurated and non-fossiliferous; showing but scant traces of brecciation.......	6
2. Brecciated bed, composed of slate colored fragments of very hard, fine-grained limestone imbedded in a matrix of fine-grained, calcareous material that is lighter in color. Many of the fragments show delicate, closely crowded lines of lamination; no fossils......................	11
1. Ledge of yellow colored, fine-grained limestone, which is finely laminated, and weathers into thin fragments. In places this bed shows small brecciated areas, without fossils........	10

Residual Materials.

Geest or residual materials that have been derived from the decay of the native rocks of the county are conspicuous at numerous points over the area of the Niagara outcrop. They present two phases, one of which consists of yellowish, incoherent grains of dolomite sand, and the other is composed of angular chert fragments imbedded in a small amount of tough, reddish colored clay. Both of these phases are a product of the secular decay of the Niagara dolomite.

The sandy phase of the geest is encountered over the the foothills and along the wagon road near the east side of section 3, and between sections 10 and 11 of Smithfield township. Such sands are also abundant at the base of the Niagara escarpment and along the wagon road across the center of section 36, Illyria township. They are present at several other points where the cutting of the streams has long exposed ledges of the more granular dolomite to the action of weathering.

Residual cherts underlie the loess and drift over the greater portion of the townships of Fairfield and Smithfield. They are mingled with the ferruginous clay and gravel that are exposed in the roadside in the southwest ¼ of section 29, Illyria township, and near the middle of section 12 of Fairfield township. They appear at the top of a bluff near the south side of section 19, Pleasant Valley township. Red colored, residual products, containing occasional pebbles and bowlders, overlie the Niagara limestone at Williams' quarry, and they are present in the roadside near the middle of section 15, Westfield township. Such materials are usually to be seen overlying the dolomite in the northeastern portion of Fayette county.

PLEISTOCENE SYSTEM.

All of the deposits of the Pleistocene system in Iowa consist of unconsolidated materials. They rest unconformably upon, and are separated by an enormous time interval from, the rocks of the Paleozoic and Mesozoic groups.

The Pleistocene materials are composed of sheets of glacial drift and beds of fluvial and wind deposits. Of the Glacial series there are represented in Fayette county the deposits of the pre-Kansan, the Kansan and the Iowan ice ages. The known aggregate thickness of the glacial deposits of our area varies from zero to more than one hundred and fifty feet.

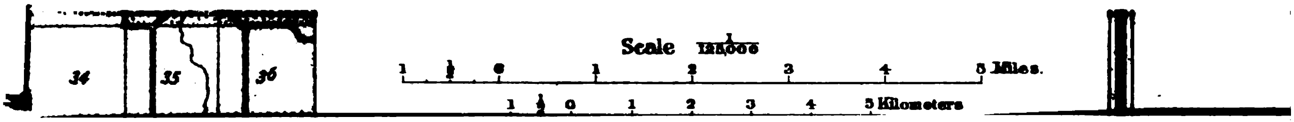
PRE-KANSAN STAGE.

Some years ago the Chicago Great Western Railroad Company made a cut thirty feet in depth through a ridge of Pleistocene materials a short distance southeast of the town of Oelwein. The sides of this cut have since slipped down to some extent, and they are at present somewhat sodded over. The following section of this exposure is taken from a report that was given of the same, at a meeting of the Iowa Academy of Sciences* soon after the excavation was made.

*Beyer: Proc. Iowa Acad. Sciences, Vol. IV, p. 59.

		FEET.
5.	Bowlder clay, rather dull yellow in color; the upper portion modified into a thin soil layer. Large bowlders, mainly of granite, are present often resting on or partially imbedded in the deposits lower in the series. (Iowan)...........	0–10
4.	Sand and gravel, not a continuous deposit; often showing water action expressed in parallel stratification lines and false bedding. The gravels are usually rather fine and highly oxidized. (Buchanan)..................................	0–2
3.	Till, usually bright yellow above, grading into a gray-blue when dry or a dull-blue when wet, below. This deposit is massive and exhibits a tendency to joint when exposed. Decayed granite bowlders are common. (Kansan)......	3–20
2. (a)	Fine-grained, white sand, much waterworn; often with a slight admixture of silt and clay...	0–½
(b)	Vegetable layer and soil, from two to four inches of almost pure carbonaceous matter, with one to three feet highly charged with humus. The peaty layer often affords specimens of moss (Hypnum) in a perfect state of preservation. (Aftonian)..................................	0–4
1.	Drift, greenish blue when wet or gray-blue with a greenish cast when dry. Greenstones and vein quartz pebbles predominate. (Pre-Kansan)..	10

In the foregoing section the first member represents a bed of pre-Kansan drift which exhibits this material in its typical bluish color and with its characteristic constituents of greenstone and quartz pebbles and small bowlders. While the sides of the excavation were fresh and unweathered this cut furnished one of the most satisfactory exposures of the pre-Kansan drift that has been found in the state. Owing to the fact that the succeeding Kansan ice sheet carried an exceedingly large amount of glacial detritus, and that it was even more widely extended than the pre-Kansan, the latter drift can be observed in our state only at rare intervals where excavations or erosion have cut through the deep mantle of Kansan materials at such fortunate points as to reveal a bed of older drift underlying it.


34
35
36
Scale 1/125,000
1 ½ 0 1 2 3 4 5 Miles.
1 ½ 0 1 2 3 4 5 Kilometers

AFTONIAN STAGE

The second member of the Oelwein section represents a layer of carbonaceous matter which was derived from the products of plant decay through a long series of years. In the lower portion of this member there occurred a compact bed of moss which contained no admixture of foreign matter. A large proportion of this moss bed was made up of the well preserved remains of a single species, *Hypnum (Harpidium) fluitans* Linn. Besides the above species Professor Holzinger and Dr. G. N. Best* have found occasional stems of two other aquatic forms, *Hypnum (Harpidium) revolvens* Swartz, and *Hypnum (Calliergon) richardsoni* Lesq. and James. Numerous fragments of the wood, branches and roots of some coniferous trees were found in the lower portion of the till immediately overlying number 2. These are probably the remains of trees that flourished over the Aftonian surface, and which were overwhelmed by the advance of the Kansan glacier. Professor Macbride† has considered these wood fragments to be identical with that of *Larix americana* Mx.

It is worthy of note that the moss species, whose remains were found in the second member of the section, as well as the pieces of larch wood that came from the horizon of the old Aftonian surface, are forms that thrive at present in more northern latitudes. It is probable that the climatic conditions of the Aftonian interglacial age were, at least toward the close of the interval, less mild and genial in this portion of our country than those which the region has enjoyed in recent times.

KANSAN STAGE.

Kansan Drift.—A very large proportion of all the Pleistocene deposits that occur in Fayette county is composed of Kansan drift. Over all but the northeastern portion of the area the mantle of the Kansan material is deep. A well put down in the southwest ¼ of section 26, Smithfield township, on land owned by W. B. Stevenson, penetrated 114 feet of superficial

*The Bryologist, November, 1903.

†Macbride: Proc. Iowa Acad. Sciences, Vol. IV, p. 65.

materials before the indurated rock was encountered. In drilling a well, one mile west and one-half mile north of this place, a thickness of 130 feet of these deposits was passed through. A well put down one-half mile east of Mr. Stevenson's, on the farm of William Gordon, penetrated 112 feet of drift. In each of the above wells, much the greater part of the depth was through drift of Kansan age.

Over a large portion of the surface of the county the Kansan till is buried beneath the more recent deposit of Iowan drift, or is covered by a blanket of loess or sand that was laid down over the extra-Iowan areas. Here, as elsewhere in the state, the top of the Kansan drift shows evidence of having been very long exposed to erosion and to the leaching and oxidizing action of the atmosphere before it was covered by the later deposits. On the slopes and along the ravines where recent erosion has exposed this till, the upper portion of the material has been leached of its lime constituent for some depth. The small amount of iron which this part of the drift contained has been so completely oxidized that it imparts a reddish-brown color to a depth of two or three feet. This red, ferretto zone grades downward to a less perfectly oxidized, yellow colored bowlder clay which, at a depth of ten to fifteen feet, merges gradually through gray into bluish colored till of the unchanged Kansan deposit.

The upper, leached and oxidized portion of the Kansan drift sheet is very uneven. The later drift and the beds of loess and sand were spread over a surface that was deeply furrowed by erosion.

The crystalline pebbles and bowlders of the Kansan till in Fayette county are such as are characteristic of this deposit in other portions of the state. The bowlders are seldom of large size. Many of them show beautifully polished and striated surfaces. Masses of dark colored, microcrystalline trap or greenstone predominate. Quartz fragments are common, and granite bowlders are not rare. Many of the latter are in an advanced stage of disintegration.

In the extreme northeastern portion of the county the greater part of the drift material has been removed by erosion, yet it

seems probable that the Kansan ice sheet overspread the entire area, and left its mantle of glacial detritus over all of the surface. At numerous points in the townships of Fairfield and Westfield the soil band is underlain by residual cherts, which are mingled with crystalline pebbles and small bowlders and imbedded in a matrix of highly ferruginous clay. Exposures of such materials are common along the roadsides. They may be seen near the middle of the east half of section 15 of Westfield township, and near the southwest corner of section 29, Illyria township.

Highly oxidized Kansan drift, overlain by loess, may be seen in the northeast ¼ of section 2, and near the southeast corner of section 10 of Union township. Such materials are exposed a short distance north of the middle of the south side of section 10, and about the middle of the line between sections 5 and 6 of Dover township. They also appear near the middle of the south side of section 36, in the same township.

Granite and greenstone pebbles and bowlders, mingled with clay, may be seen in the wagon road a short distance east of the middle of the line between sections 1 and 12 of Clermont township, and near the middle of the line between sections 13 and 24 of the same township. Such drift materials also appear near the middle of section 8, and of section 17, Clermont township. The superficial materials that overlie the Niagara limestone at Williams' quarry contain occasional pebbles and small bowlders, and seem to consist, in part, of glacial till. Along the top of the bluff northeast of the town of Clermont bowlders of crystalline rock two to three feet in diameter are not rare. It seems probable that the margin of the Kansan glacier extended but a short distance east of this portion of Fayette county.

Buchanan Gravels.—The Buchanan gravels are derived from the Kansan drift. They were separated from the finer constituents of the drift by the sorting action of water, and were deposited along the channels of the turbulent streams which carried off the water that resulted from the melting of the Kansan glacier. Thus, in point of age, the Buchanan gravels were contemporaneous with the withdrawal of the Kansan ice

sheet. They belong to the very latest portion of the Kansan stage and the very beginning of the Yarmouth.

The deposits of Buchanan gravel present two phases. Sometimes they consist of very coarse materials in which bowlders ranging in size from a few inches to one foot in diameter are not rare. Such deposits are known as the upland phase. Other

FIG. 68. Buchanan gravels in a pit at West Union. Cross-bedding is conspicuous at the right in the picture.

beds are composed of sand and small pebbles, a large proportion of which are less than one inch in diameter. These deposits constitute the valley phase.*

* NOTE.—For a discussion of the genesis of these phases of Buchanan gravel, see Iowa Geol. Surv. Vol. VIII, p. 241, *et. seq.*, and Vol. XIII, p. 67.

All of the beds of the Buchanan gravel that were seen in Fayette county belong to the valley phase. That they were laid down by streams whose currents were exceedingly variable is indicated by the lack of uniformity in the size of the constituent materials, and in the cross-bedding which is a very common and conspicuous feature of these deposits. This will appear in figure 48. The materials are usually much weathered and very strongly stained with iron. The beds vary from three or four feet to more than twenty feet in thickness. Sometimes they occur in broad belts along the lowlands as if the streams which carried them initiated drainage lines that have since been followed. They are sometimes found over the uplands; occasionally forming ridges or elevations which rise some feet above the general level of the surrounding surface. In such cases it would seem probable that they were laid down while the ice still occupied the areas that now appear as the lower lands. Beds of Buchanan gravel are exposed at a number of points in Fayette county. Their distribution is indicated on the accompanying map of the Superficial Materials of the area.

IOWAN STAGE.

Iowan Drift.—During the greater part of the Yarmouth interglacial interval, and all of the Illinoian glacial, and the Sangamon interglacial ages the surface of the Kansan drift in Fayette county was subjected to the erosive action of the rains and streams, and to the chemical action of the amosphere and of the products of plant decay. It was during these ages that the profound leaching and oxidation and erosion of the upper portion of the Kansan drift were largely accomplished.

The Iowan ice sheet covered nearly two-thirds of the area of Fayette county. Its limits have been traced under the discussion of Topography. The drift of this age is thin. In many places over the Iowan plain very slight erosion has exposed the oxidized surface of the Kansan. Where the Iowan drift can be well seen, as in the southeast ¼ of section 27, Jefferson township, it consists of yellow clay which carries numerous bowlders

of coarse-grained, gray or pink granite. The Iowan surface is practically uneroded, unleached and unoxidized, and its bowlders of granite show but slight signs of decay.

A very conspicuous and characteristic feature of the Iowan drift area is the very numerous bowlders of large size that are strewn over the surface. Such large granite masses are conspicuous in the townships of Jefferson, Oran, Fremont, Banks and Bethel. Near the eastern border of the Iowan drift plain the bowlders are even more abundant, but they are usually much smaller in size. At several points in the townships of Putnam, Smithfield and Windsor they have been gathered from the fields and thrown in great piles, or heaped in long windrows along the roadsides.

There seems to be little order or regularity in the distribution of the bowlders. Over some portions of the Iowan area they are sparsely scattered, while over others they are strewn so thickly as to be serious obstacles to the cultivation of the land. They are decidedly more abundant over the marshy depressions and along the flanks of the swells. The causes which resulted in leaving much the greater number of Iowan bowlders over the lower lands seem somewhat obscure. They could hardly have been exposed in the depressions through the action of erosion in removing the finer constituents of the drift, for the surface over these portions of the Iowan plain seems to have suffered almost no erosion, and exists today practically as it was left when the Iowan glacier melted from the region.

Professor Calvin* has shown that the bowlders that were carried by the Iowan glacier were imbedded in the lower surface of the ice. As the ice sheet moved over slight and relatively narrow concavities the pressure upon these sub-glacial bowlders would be partially relieved, and there would be a tendency for some of them to become permanently lodged in the depressions.

The Iowan ice sheet was comparatively thin and it carried but a small amount of glacial debris. Owing to the wide extension of such a thin ice sheet, it is probable that the line of ice movement, within some miles of the margin, fluctuated

*Calvin: Iowa Geol. Surv., Vol. XIII, pp. 285 and 286.

with the climatic variations during successive series of years. There may have been periods during which, toward the glaciers' margin, the movement ceased and the ice became dead and melted where it came to rest. Then again there would probably return conditions that would favor the advance of the line of ice movement. During the periods of slackened movement of the glacier, as the dead ice melted the bowlders which it bore would be left irregularly distributed upon the drift surface. They could not have been buried to any great extent on account of the small amount of fine detritus that the Iowan ice sheet carried. With another advance of the ice movement the loose bowlders that were left over the surface would be pushed forward by the ice for a short distance until they became stranded in the depressions which, then as now, were abundant over the Iowan surface. It would seem probable that the distance the bowlders were moved, in this final shifting of their position, would be too short, and the ice mass at such points would be too thin to result in abrasion to an extent that would leave permanent marks of glaciation upon them.

The Iowan Loess.—The homogeneous, fine-grained, yellow colored, superficial material, called loess, forms a thick mantle over all of the Kansan drift area, except where it has been removed in the development of the channels of the streams. While the deposit of loess is deep over all of the Kansan drift plain, it shows the greatest depth over a belt adjacent to the Iowan border. As is usual around the immediate margin of the Iowan area, the deposit of loess is so thick over the hills that their summits stand several feet higher than those at some distance from the Iowan plain. A few knobs and ridges that lie within the Iowan drift area are also crowned with loess.

The Iowan loess, like the Iowan drift, is a very recent deposit as compared with the Kansan till upon which it rests. It is largely unleached of its lime constituent and seldom shows more signs of oxidation in one portion than in another.

Professor Calvin has shown that the loess which forms a thick deposit for a width of some miles around the margin of the Iowan plain was probably derived from the Iowan drift by some process of transportation outward from the Iowan gla-

Over the greater portion of the Kansan drift area the soil has been developed upon a deep mantle of loess. This loess soil is fine-grained, is quite porous, and contains an abundance of lime. Where the slopes are not so steep as to cause rapid rainwash, and thus prevent an accumulation of humus in the superficial portion, this loess soil ranks with the best in its endurance and productiveness. Areas of exceptionally fertile loess soil occur north of West Union, and east of the village of Taylorsville. Too often, however, the loess areas are very hilly, and unless great care is exercised in their cultivation, the rains furrow the fields with gullies and soon remove the humus and other plant foods that may have accumulated previous to the attempts at tillage. When this soil has never been disturbed by the plow it produces the best of crops of blue grass. Even the steeper slopes furnish excellent pasturage which grows constantly better with the passing years.

Along the flood plains of the streams there has been developed an alluvial type of soil of superior quality. Over these level areas leaching and washing are at the minimum. This alluvium usually consists of the very cream of the superficial materials that has been washed from the slopes of the basin which is drained by the respective streams. The subsoil is usually sufficiently porous to insure good underdrainage. Where these soils are not too sandy, they are prevailingly productive and rank among the best in endurance.

The most important alluvial areas are found over the flood plain of the Turkey river, and along the Little Turkey river and the Volga. Small tracts also occur along Otter creek in Pleasant Valley township. A belt of Iowan drift, slightly modified by alluvial materials, borders the Wapsipinicon river in Oran and Fremont townships, and Crane creek in the township of Eden.

All of the facts that are presented by the loess in Fayette county are consistent with, and are best explained by, the assumption that it was transported and deposited by currents of air; and that the greater portion of the material was laid down contemporaneous with the invasion of the Iowan glaciers and immediately succeeding their withdrawal. There seems no doubt but that wind deposits somewhat resembling the Iowan loess materials are taking place at the present time. It is not unlikely that a portion of this fine-grained material in Fayette county has been shifted, worked over, and redeposited since the Iowan age.

In the southern and western portions of the state, the thicker beds of loess are found in such a relation to the channels of the larger streams as to indicate that this material might have been gathered by the winds from the flood plains and alluvial bars, and deposited on the bluffs or slopes of the uplands, in places where the air currents were obstructed or where the dust-like material was caught and retained by vegetation. It seems certain, too, that at several other points in the state there are areas in which the loess can not be referred to the Iowan age, and in which beds of loess are exposed within relatively short distances which are not contemporaneous deposits.* However, in this portion of the state, and further south in the counties of Tama, Benton and Johnson, the much more intimate relation which the thickest deposits of loess sustains to the Iowan border than to the valleys of the larger streams makes the impression in the field overwhelmingly in favor of the greater portion of this accumulation having taken place during, and immediately following, the stage of Iowan glaciation.

Iowan Gravels.—Deposits of unweathered gravels of Iowan age appear in the upper part of the gravel terrace that is exposed at various points along the Turkey and Little Turkey rivers. The fresh character of the upper gravels as compared with the very ferruginous and decayed materials at the base is well shown at the exposure near the Huntsinger bridge, two and one-half miles east of Eldorado. See figure 36 on page 452. At this place there are seen occasional lens-shaped masses of loess imbedded in the coarser terrace material. One such

*See Iowa Geol. Survey, Vol. XIII, pp. 328-330.

body of loess, buried beneath eight feet of gravels measured fourteen feet in length and had a maximum height of three feet. It contained a number of fossils among which several individuals of two or three of the more common loess species were collected. This loess mass was underlain with a depth of two or three feet of fresh looking gravel, below which there was exposed a thickness of about eight feet of old and much iron-stained terrace material.

There is no place in the immediate locality from which it seems probable that these lenses of loess could have slipped down to their present position. Possibly such masses are fragments of pre-Iowan loess bodies; or it may be that they became detached from beds that were deposited on the slopes beyond the Iowan margin, while this ice sheet occupied the area a short distance to the west. During the time of melting of the Iowan glacier, and while the flooded streams were carrying ice floes and coarse material, such masses may have been dislodged from the place of their deposition, and having slid down upon cakes of ice they could be carried without disturbance, while frozen, and imbedded with the accumulating terrace deposit.

DEFORMATIONS AND UNCONFORMITIES.

A slight folding of the strata may be seen in the east bank of a small stream near the middle of the east side of section 19, Clermont township. See figure 40 on page 472. The horizon of *Orthis whitfieldi*, in the Lower Maquoketa beds, is involved in this flexure. It seems probable that the deformation here is due to a local creeping of the shales under pressure from the hill above, rather than to a widespread crumpling of the layers.

Where the Niagara strata are exposed in the railroad cut, at the "Backbone", about two and one-half miles southeast of West Union, the layers show undulations in which the low anticlines are one to one and one-half feet in height. A fold in the Niagara limestone, eighty to one hundred feet in vertical height, is indicated by the outcrop of layers of the *Newberria*

johannis zone of the Devonian strata, in the town of Fairbank, at an altitude forty feet lower than the top of the Niagara ledge that is exposed two miles to the northward, in the east bank of a branch of the Wapsipinicon river. In the deep railroad cut, at Fayette, small undulations appear in the layers of the Wapsipinicon stage at the base of the Lower Davenport breccia. The crushed and shattered materials near the top of the Wapsipinicon deposits form another example of deformation in the Devonian strata.

The most conspicuous unconformity that was encountered in this area is that between the Pleistocene deposits and the indurated beds upon which they rest. The loess and the Iowan drift were also spread unconformably over the eroded surface of the Kansan till.

Soils.

A considerable variety of soils is represented in Fayette county. The most productive type, and the one most widely distributed, is that which has been developed upon the Iowan drift. This soil is dark colored and usually deep. It is generally rich in humus and in all of the plant foods that result from the decay of organic matter. In this soil the mineral constituents are unleached and undecayed. It contains an abundance of lime and other inorganic substances that contribute to the growth of plants. This soil is so granular and porous that it does not run together or bake from the effects of excessive rains. It is light and warm, and easily worked. It responds most generously to intelligent methods of cultivation, and is altogether one of the most fertile, satisfactory and important soil types found in the state.

There are occasional areas over the Iowan plain in which the drift has been modified by a more recent deposit of windblown sand. Such tracts are more common in the vicinity of the larger streams over the townships of Jefferson, Oran, Fremont, Center and Eden. Such soil is warm and mellow. It is favorable for maturing early crops, but it is less productive and more sensitive to drouth than the soil on the more typical Iowan drift.

Over the greater portion of the Kansan drift area the soil has been developed upon a deep mantle of loess. This loess soil is fine-grained, is quite porous, and contains an abundance of lime. Where the slopes are not so steep as to cause rapid rainwash, and thus prevent an accumulation of humus in the superficial portion, this loess soil ranks with the best in its endurance and productiveness. Areas of exceptionally fertile loess soil occur north of West Union, and east of the village of Taylorsville. Too often, however, the loess areas are very hilly, and unless great care is exercised in their cultivation, the rains furrow the fields with gullies and soon remove the humus and other plant foods that may have accumulated previous to the attempts at tillage. When this soil has never been disturbed by the plow it produces the best of crops of blue grass. Even the steeper slopes furnish excellent pasturage which grows constantly better with the passing years.

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of shale from a zone in the upper part of the Lower Maquoketa beds. The pit is located about one-half mile east of the plant, and the shale is conveyed to the works on wagons. There is exposed in the pit about twenty feet of shale which is overlain with much decayed residual products of the Middle Maquoketa beds. See figure 51. The shale is quite hard, and becomes plastic after weathering or soaking in water.

Results of the rational and ultimate chemical analyses of this shale are given below.*

Silica	28.82
Alumina	10.37
Combined water	16.24
Clay and sand	55.43
Iron oxide	3.76
Lime	19.14
Magnesia	5.40
Potash	5.38
Soda	7.41
Total fluxes	41.09
Moisture	0.43
Sulphur trioxide	3.01

RATIONAL ANALYSIS.

Clay substance	73.32
Feldspar	4.93
Quartz	21.76
Total	100.01

The wares made from the shale alone shrink but little in burning and are almost white in color. Loess is mixed with the shale in varying proportions to impart a richer color to the products. Construction brick, drain tile, hollow block and sidewalk blocks are manufactured in white, mottled and red colors.

*Iowa Geol. Surv., Vol. XIV, p. 898.

dressed stone and range material that is marketed in this area. A view of the ledge worked is presented in figure 50. The bed consists of thick, homogeneous layers at the base of the Niagara. The stone is quarried in large blocks by the "plug and feather" method. These masses are then sawed to the desired dimensions, by means of large steel blades which work back and forth horizontally and are constantly supplied with water and sand. The distance between the saws can be adjusted to cut slabs of any desired thickness. The sand used for cutting is rather angular, coarse-grained and very ferruginous. It is taken from a hill in the edge of Clayton county, and represents an exceptionally fine-grained bed of the valley phase of the Buchanan gravels. The quarry furnishes sawed stone for sills, water tables, side walk crossings and range work. The greatest demand is for trimmings for buildings.

Crushing tests were made at the University of Wisconsin on five two-inch cubes of this stone with an average result of 5,280 pounds per square inch. The dimension stone is hauled on wagons and loaded for shipment at the stations of Clermont and Postville. A market for the products is found in many of the larger towns of northern Iowa, and west into South Dakota.

The Williams and Davis quarry, about two and one-half miles southeast of West Union, is worked in the cherty phase of the Niagara limestone. No stone suitable for shipment is produced at this place. At a number of points in the townships of Fairfield and Auburn small quantities of stone are taken from Niagara layers to supply a local demand.

Devonian Limestone.—Layers of Devonian limestone, from a zone between the horizon of very abundant *Gypidula comis* and that of *Acervularia profunda*, are worked at a greater number of more widely separated points than any other rocks of the county. Stone of this horizon is quarried at a number of places, near the top of the bluffs, in the town of Fayette. The layers here are more or less broken and furnish a yellow, earthy, magnesian stone of excellent quality. Materials which correspond in color, lithology, and geological position with those worked at Fayette are quarried in the northwest ¼ of

section 6, Windsor township, and also in the extreme northwest corner of section 2 of the township of Bethel. Small quarries are also operated in the rocks of this horizon near Alpha and Waucoma, in Eden township.

In the vicinity of Maynard and Fairbank the stone that supplies the local demand is taken from beds that are the equivalent of those worked at Fayette, but the material is much less magnesian. Blocks of desirable size are not so readily obtained from these non-magnesian layers, and the materials are much less durable.

Lime.

There is no lime burned in commercial quantities in Fayette county. In the vicinity of Auburn a small amount of the Niagara limestone is burned each year in rude, inexpensive kilns. The stone is here a remarkably pure carbonate of calcium, and the quality of the lime that is produced is equal to the best grades that are made from lime carbonate. At a few other points over the Niagara area the immediate neighborhood needs are supplied by burning an occasional small kiln of stone.

Clay.

The clay resources of this area are for the most part undeveloped. A large amount of the clay products that are used in the county are imported. Clay goods are manufactured at two points, near Oelwein and at Clermont.

Oelwein.—The plant of the Oelwein Pressed Brick Company is located one mile north and one mile west of Oelwein. It is owned and operated by Mr. J. C. Knapp. The clay is taken from a pit in the Kansan drift which shows the following section:

	FEET.
3. Moderately coarse sand	2
2. Deposit resembling the valley phase of Buchanan gravel	1
1. Bed of clay in which pebbles and small bowlders are not abundant. Upper ten feet yellow in color, blending into bluish-gray at the base.	14

In this pit the materials of the second and third members are stripped away as waste. The entire thickness of number 1 is utilized. The clay is passed through a crusher which consists of double rolls, one with pins and one with perforations. These work in such a manner as to sort the most of the pebbles from the clay and to pulverize those that remain. The plant is equipped with one stiff mud, and one dry press brick machine. One large Scove kiln and one Eudaly kiln are used in burning

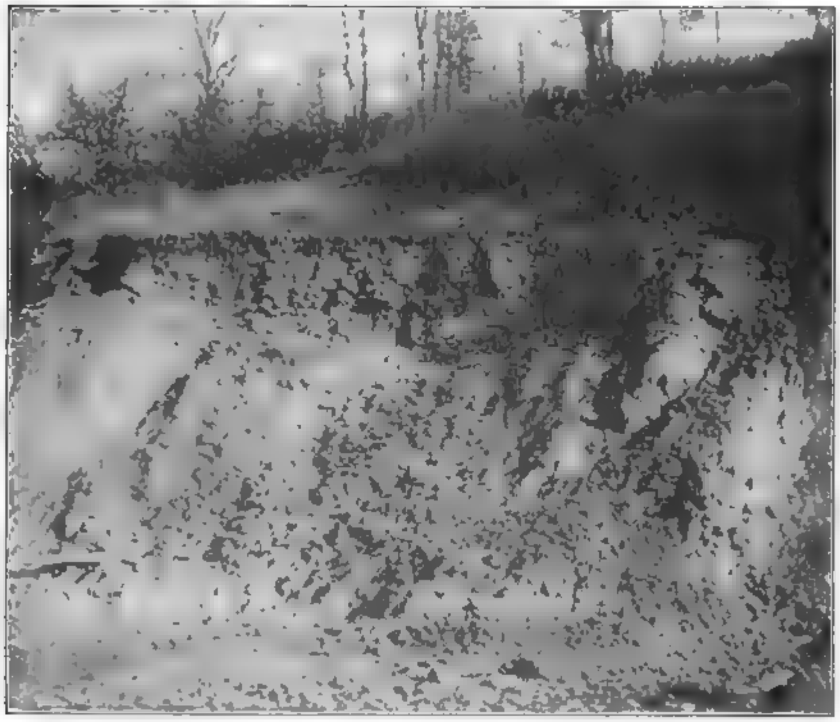

FIG. 51. Shale pit of the Clermont Brick and Tile Company. The horizon is immediately below the base of the Middle Maquoketa beds. Clermont, Iowa.

the wares. Construction brick is the only class of goods produced, and a market for all of the output is found in the town of Oelwein.

Clermont.—The Clermont Brick and Tile Company operates a clay plant in the north part of Clermont. They work a body

of shale from a zone in the upper part of the Lower Maquoketa beds. The pit is located about one-half mile east of the plant, and the shale is conveyed to the works on wagons. There is exposed in the pit about twenty feet of shale which is overlain with much decayed residual products of the Middle Maquoketa beds. See figure 51. The shale is quite hard, and becomes plastic after weathering or soaking in water.

Results of the rational and ultimate chemical analyses of this shale are given below.*

Silica	28.82
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Soda	7.41
Total fluxes	41.09
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RATIONAL ANALYSIS.

Clay substance	73.32
Feldspar	4.93
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The wares made from the shale alone shrink but little in burning and are almost white in color. Loess is mixed with the shale in varying proportions to impart a richer color to the products. Construction brick, drain tile, hollow block and sidewalk blocks are manufactured in white, mottled and red colors.

*Iowa Geol. Surv., Vol. XIV, p. 898.

In recent years common brick have been made at Hawkeye by Mr. L. A. Book, but during the past year the plant has not been in operation.

The Upper Maquoketa beds consist of a body of plastic shale in no way inferior to that used by the Clermont Brick and Tile Company. Shale of this horizon is favorably exposed at the towns of Saint Lucas, Auburn, Brainard, Lima and Wadena. Deposits of loess are also accessible near each of these points, if it might seem desirable to mix this material with the shale, as is done at Clermont. So far as the abundant supply of excellent raw material is concerned, all of the more common clay wares might be successfully manufactured at any one, or all, of the above mentioned towns in Fayette county.

Sand.

There are no deposits of merchantable sand found in the area under consideration. Gravel and finer material suitable for use in cement walks may be found along the beds of the most of the larger streams. Such materials occasionally occur in deposits of the valley phase of the Buchanan gravels. The river laid materials, when screened, furnish sand adapted for making common lime plaster and mortar. They supply practically all of the sand used in the county for these purposes.

Road Materials.

Deposits of the Middle Maquoketa rocks, and beds of the Niagara and the Devonian limestone furnish material that would make very serviceable macadam. Outcrops of such beds are fortunately distributed so that nearly every township of the county is accessible to a supply of such stone within easy hauling distance.

However great may be the desirability of macadamizing the country roads, its great cost will make such a proposition im-

practicable over a large portion of the county for many years to come. There are about seventy miles of public roads in each township, and at present the average sum of money that is annually expended on the roads of each township is less than one thousand dollars. If this entire amount could be applied towards macadamizing the roads there would be only a fraction of one mile covered each year. Under the present conditions the greater portion of the road tax in each township is required to keep all of the roads in a passable condition, without any attempt being made at permanent road building.

At the present time it would seem wiser to work along cheaper lines of road improvement. All of the country roads could be gradually graded up in such a manner that the water that falls upon them could quickly escape at the sides. A line of drain tile could be placed down the middle of the road or at the roadsides, where the subsoil demands underdrainage, and further away at points where it may be required to divert the water of a porous soil stratum from entering the roadbed. When the roads are prepared in this manner, and then a top dressing of gravel, a few inches in thickness, is applied, a very excellent and permanent roadbed is secured. The cheapness of such a plan of road improvement makes the method feasible under present conditions. Fortunately for the people of Fayette county, the beds of Buchanan gravel are abundant and well distributed over the area, as is shown on the map of Superficial Materials. The constituent particles of these deposits are of such size that without further preparation they are ready to be hauled out and applied to the road. A start has already been made in building gravel roads over this area, the success of which justifies the much more extended use of these fine gravels in building excellent, cheap and durable country roads.

Cement Materials.

In recent years the expansion of the uses to which Portland cement is applied has been extremely rapid. In some of the adjoining states the manufacture of cement has become a very important industry, but as yet there is no cement producing plant in Iowa. On this account the location in our state of deposits suitable for the manufacture of Portland cement is of more than casual interest. With this purpose in view samples were collected from the most promising localities in Fayette county, and submitted to the Survey Chemist for analysis. The samples, numbers 1 and 2, were collected from near the village of Auburn. Number 1 represents the Upper Maquoketa shale, and number 2 came from the non-dolomitized Niagara limestone that overlies the shale at this place. The results of the analyses of these two samples were reported by Professor Michael as follows:

Sample Number 1. Shale.

	PER CENT.
Silica, SiO_2	49.60
Alumina Al_2O_3	6.36
Iron oxide, Fe_2O_3	6.25
Lime, CaO	22.45
Magnesia, MgO	0.20
Soda, Na_2O	0.35
Potash, K_2O	0.90
Loss on ignition	13.56
Sulphur trioxide	0.37

Sample Number 2. Limestone.

Silica	0.68
Alumina and iron oxide	0.50
Calcium carbonate	98.52

A calculated mixture consisting of 4,049 pounds of raw shale used with 9,946 pounds of the limestone would yield, upon calcining, about 9,105 pounds of cement having a composition of silica 20.08 per cent, and calcium oxide 64.00 per cent. The purity of the limestone, sample number 2, is remarkable and

the per cent of the magnesian ingredient is extremely low. The materials here are almost unlimited in quantity, and are readily accessible. There seems little doubt that from some combination of the above shale and limestone materials a very excellent grade of Portland cement could be produced. The apparent serious drawback to the profitable working of these beds lies in the fact that the nearest railroad point is West Union, five miles distant.

Near Clermont a sample for analysis was taken from the limestone layers of the *Isotelus maximus* beds, and from the bands of shale which lie between these calcareous layers. The following are the results of these analyses:

	Limestone PER CENT	*Shale* PER CENT
Silica	11.95	33.82
Alumina and iron oxide	2.80	9.75
Calcium carbonate	84.80	56.66
Magnesium carbonate	0.45	3.17
Soda	.00	1.82
Potash	.00	4.25
Loss on ignition	.00	15.60
Sulphur trioxide	.00	1.62

A calculated mixture consisting of 11,086 pounds of the limestone with 4,147 pounds of the shale would give, after calcining, about 10,400 pounds of cement of the composition silica 27.24 per cent and calcium oxide 65.79 per cent. The proportion of silica above is larger than would be desired. It might be possible to lower the percentage of silica in other combinations of these materials without appreciably affecting the lime.

Mixtures of the limestone and shale from the *Isotelus maximus* horizon do not promise such satisfactory results as do those of the limestone and shale deposits near Auburn. However, the greater accessibility of the former deposits to railroad facilities would make it desirable for prospective cement producers to test the combinations of these materials more fully before pronouncing the beds unsuitable for cement manufacture.

Water Supplies.

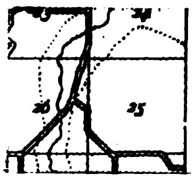
The larger streams of the area furnish an unfailing supply of water. Even their smaller affluents which rise in the seapy sloughs over the Iowan drift plain have a constant flow throughout the year. Over the greater portion of the area wells in the Pleistocene deposits furnish an abundance of water at a depth varying from twenty or thirty, to one hundred and forty feet. In the northeastern portion of the county, the top of the Maquoketa shale determines a line of springs. many of which have a perennial flow, and furnish an excellent supply of water.

Water Powers.

The large streams of the county furnish ideal conditions for developing strong water power. Along the Turkey river a well kept and well furnished mill is operated at Eldorado, and further south there is another at Clermont and still another at Elgin. Until recent years a mill has been kept up at Dover Mills, but at present the dam is out of repair. At Auburn, on the Little Turkey river, there is a well equipped mill with excellent power. Another such mill is operated at Waucoma. At the village of Alpha a mill on Crane creek does a flourishing business in flour and feed. Water power is also utilized at Fairbank on the Wapsipinicon river.

Lead.

Persistent rumors of the finding of deposits of lead reached the writer during the prosecution of the field work in this area, although careful search revealed no grounds for such reports. There are men who relate in all seriousness how in the early days lead mines were secretly worked by the Indians in this region. What is even worse they seem to expect credence to be placed in their word. The lead that is mined in Dubuque



BY

T. E. SAVAGE.

county comes from dolomitized rocks of the Galena-Trenton stage. So far as the Galena-Trenton rocks are exposed in Fayette county they consist of unaltered limestones. The great body of dolomite that occurs in this area is a later deposit and has not been known to yield any quantity of lead or zinc in this portion of the country. It is possible that small quantities of these minerals may be found in the rocks of our area, but the probability of finding workable deposits in Fayette county is too remote for serious consideration.

Copper.

Some years ago a piece of copper was found in the surface materials near Elgin. Under the stimulus of this discovery there has been considerable time and money expended in sinking a shaft in search for copper near that place. The strata penetrated include the greater portion of the Lower Maquoketa beds.

Masses of native copper have been found in the drift at various points in the state.* Such fragments were brought down by the glaciers from the north at the same time that the crystalline bowlders, found in the Kansan drift, were transported to their present position. It is needless to say that the presence in the drift of occasional fragments of copper furnishes absolutely no indication of deposits of this mineral in the underlying rocks of the state.

Gold.

In the early years of the settlement of Fayette county gold was panned in small quantities from the gravel and sand along the channels of a number of the streams. Mr. C. E. Allen of West Union is authority for the statement that the gravels in the bed of Otter creek, a short distance southwest of West Union, have yielded to the patient washer from one dollar to a

*Geology of Benton County, Iowa Geol. Surv., Vol. XV. p. 228.

dollar and twenty-five cents per day. Doctor Parker, of Fayette, has panned gold out of the sands of Alexander creek, south of Fayette. Responsible parties state that gold was exploited with small returns in the gravels and sands of Bear creek a short distance east of Cornhill, in Fairfield township.

In each of the above cases, as with all the gold found in our state, the minute particles of the precious metal were disseminated in the drift, with which material they were brought down by the ice sheets from the northern ledges. These particles have become segregated in the sands and gravels along the streams by the sorting action of the water. The presence of minute grains or scales of gold along the beds of the drift streams is quite common in Iowa, and in other states.* Like the finding of copper, the presence of such gold particles in the sands that have washed out of the drift is no indication that such materials occur in the native rocks of our state.

ACKNOWLEDGMENTS.

The writer desires to acknowledge his indebtedness to Professor Calvin who kindly identified many of the Maquoketa and Niagara fossils. Prof. G. E. Finch of Marion also rendered valuable assistance in the field. Prof. Bruce Fink, Mr. A. G. Becker and Mr. Wm. Lavelle have placed the writer under obligations for information given and service rendered. This opportunity is taken to extend to each of the above mentioned persons most cordial thanks.

*Annual Rept. Geol. and Nat. Hist., Resources of Indiana, 1901-02, pp. 20-28. See also, Iowa Geol. Surv. Vol. XI, p. 18. *et seq.*

INDEX.